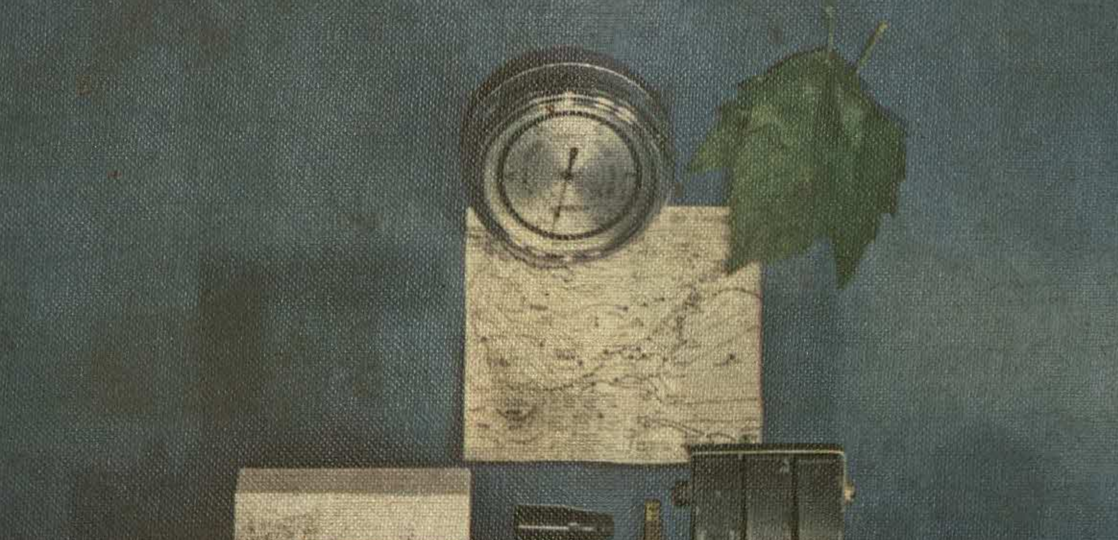


SCIENCE a modern approach

SL- 1514.
~~4588~~

3714
13.1.87

A
344

457

STATE INSTITUTE OF EDUCATION

SCIENCE a modern approach 5

STATE INSTITUTE OF EDUCATION
MANIPUR

SCIENCE

SCIENCE CONSULTANTS

Owen Chamberlain, A.B., Ph.D.
Professor of Physics
University of California
Berkeley, California

Robert C. Stebbins, A.B., M.A., Ph.D.
Professor of Zoology
University of California
Berkeley, California

MATHEMATICS CONSULTANT

Leonard Simon, B.S., M.A.
Acting Assistant Director
Bureau of Curriculum Research
New York, New York

READING CONSULTANT

Theodore E. Glim, A.B., M.A., Ed.D., Ph.D.
Assistant Superintendent of Instruction
Shoreline Schools
Seattle, Washington

CURRICULUM CONSULTANT

Alexander Pepe, B.A., M.A.
Elementary Science Teacher
East Side School
Cold Spring Harbor, New York

SCIENCE MATERIALS CONSULTANT

Nick Oddo, B.A., M.A.
Elementary Science Cooperative Support Teaching Project
Berkeley Unified School District
Berkeley, California

Holt, Rinehart and Winston, Inc., New York

a modern approach 5

Abraham S. Fischler

Lawrence F. Lowery

Sam S. Blanc

S.C.E.R.T., West Bengal
Library
Calcutta
25/3 B. C. Road

S.C.E.R.T., West Bengal
Date 13-1-87
Acc. No. 3714

AUTHORS

Abraham S. Fischler
Professor of Science Education
University of California
Berkeley, California

Lawrence F. Lowery
Teacher-Principal
Oakland Unified School District
Oakland, California

Sam S. Blanc
Director of Science and Mathematics
Cajon Valley School District
El Cajon, California

Illustrated by
Mary Gerard, and staff
Gerald M. McConnell

Cover design by Aaron Heller

Copyright © 1966 by Holt, Rinehart and Winston, Inc.
Certain portions of this work have been
previously published and copyrighted 1963
by Holt, Rinehart and Winston, Inc.
All rights reserved
Printed in the United States of America
4-2831-0916

CONTENTS

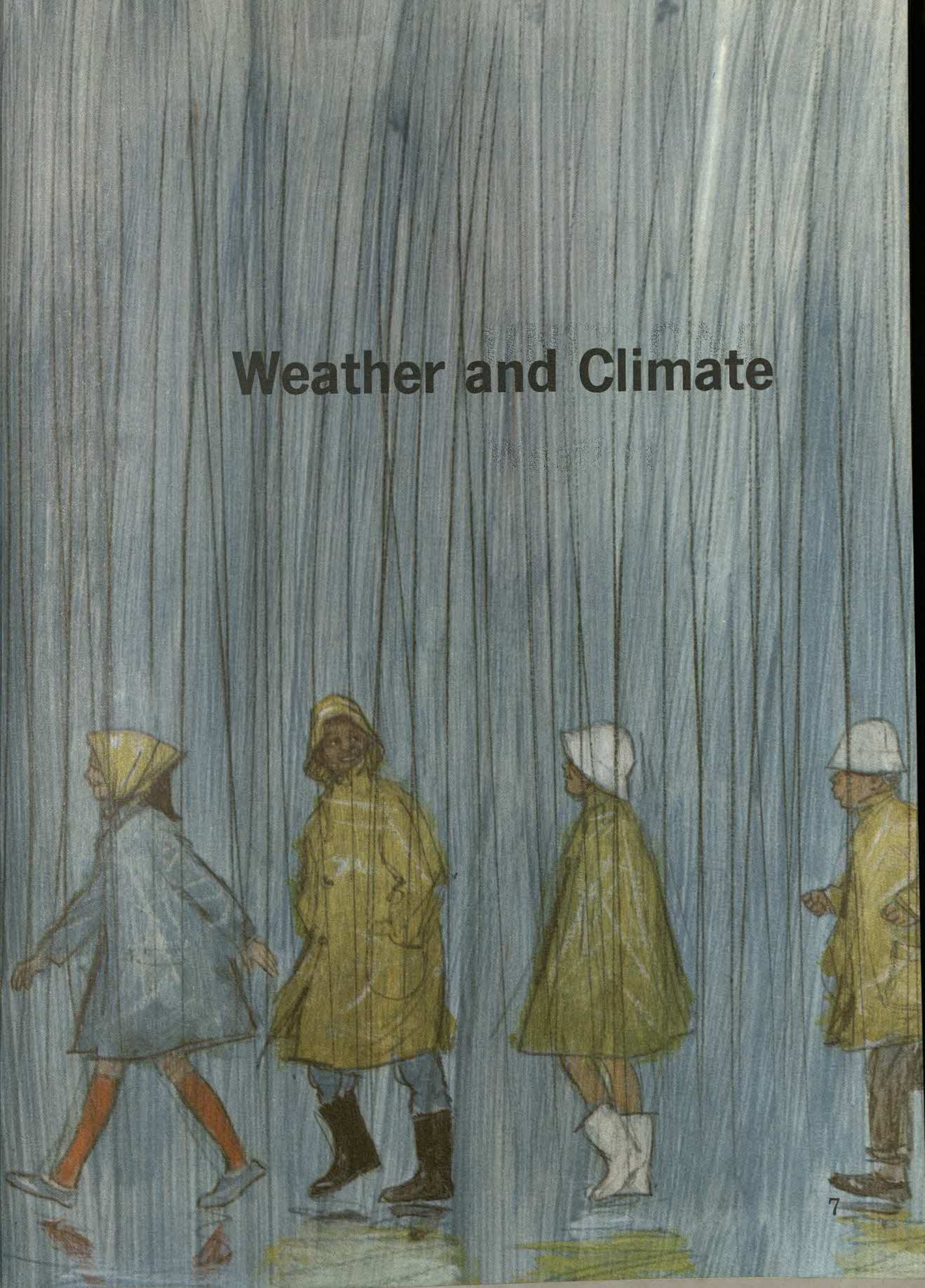
Unit 1 Weather and Climate 6

Unit 2 Atmosphere, Oceans, and Space 88

Unit 3 Forms and Functions in Living Things 186

Unit 4 Electricity and Magnetism 254

Weather and Climate



WEATHER TODAY
CLOUDY
COOL
LIGHT RAIN
TONIGHT
CONTINUED

Weather Forecasts

Before starting for school each morning, you probably listen to a weather forecast. How would you prepare for the day if you heard the following report?

"Cloudy and cool with light rain today, highest temperature in the 50's, northerly winds 10 to 15 miles an hour; cloudy and cool tonight and tomorrow, lowest temperature tonight in the 40's. Eight A.M. temperature reading, 47 degrees; humidity, 86 percent; barometer, 29.9 and falling."

At eight o'clock in the morning, how is it possible to predict the temperatures you can expect in the next twenty-four hours?

How can the weatherman tell how fast the wind is blowing? What is the direction of a "northerly" wind?

What is a "barometer," and what do we mean when we say it is "falling"?

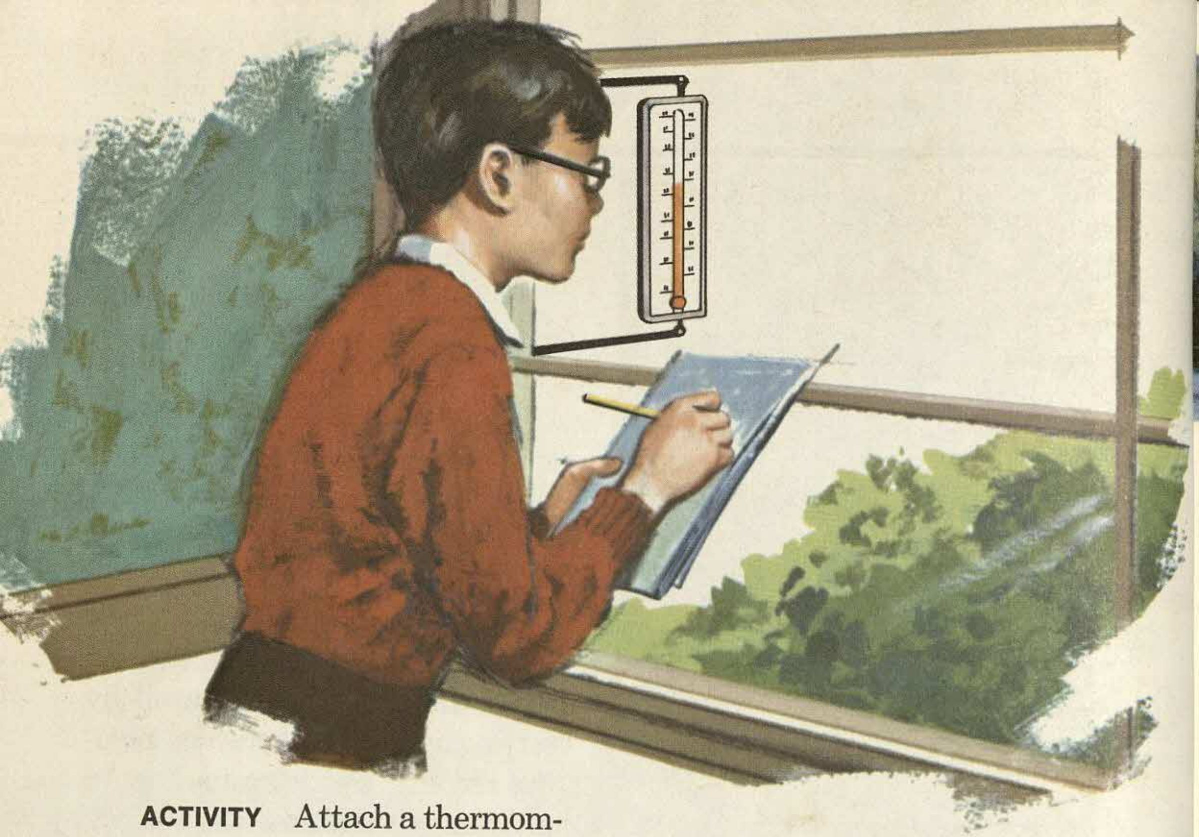
How does the weatherman know that it is going to rain? What does "humidity" mean?

As you learn more about weather and climate, you will be able to answer these and many other questions. You can become a weather forecaster yourself by setting up a weather station, keeping records, and learning how to interpret the information you collect. The Greek word "meteora" means "things in the air." The scientific study of weather is called meteorology (mee-tee-er-OL-uh-jee). Can you explain why this word was chosen to describe weather? What is a meteorologist?

Temperature

Recording Temperature

You can tell that the air is cold or warm simply by stepping outside. The meteorologist, of course, must rely on more than his feelings. What instrument tells you if the air is warm or cold?

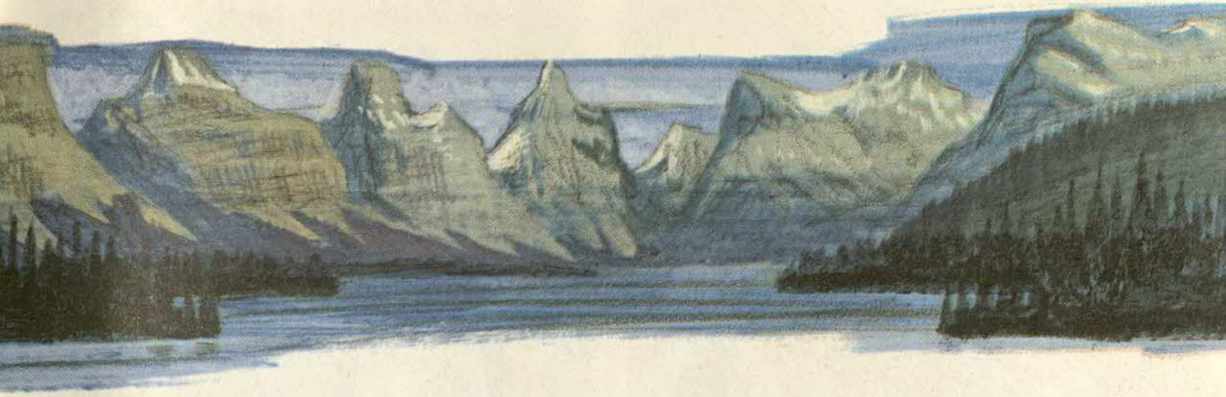


ACTIVITY Attach a thermometer outside a classroom window. Shield the thermometer from the direct rays of the sun. Record the temperature twice each day, once in the morning and once in the afternoon. Check the temperature at the same time each morning and each afternoon. Record the temperature readings on charts.

WEEKLY TEMPERATURE CHART

*Week of*______	*A.M.*	*P.M.*
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		

After you have recorded your temperature readings for a week, make a line picture of your readings. What is your highest reading? What is the lowest reading? What is the difference between them? How many horizontal lines will you need? How many vertical lines will you need for the time-day readings? Find the point where your time-day line crosses the correct temperature line. Put a dot at that point. Do this for each time-day line. Use a ruler and connect the dots in order. What do you notice? How did the



temperature change? What would you predict about the temperature change during a day? How could you check your prediction? Did the temperature change the same amount each day?

Make a line picture of the average weekly temperatures for a month. Keep each month's chart. At the end of each month compare the readings with those of the month before. How do you predict the readings will change? Why do temperatures change?

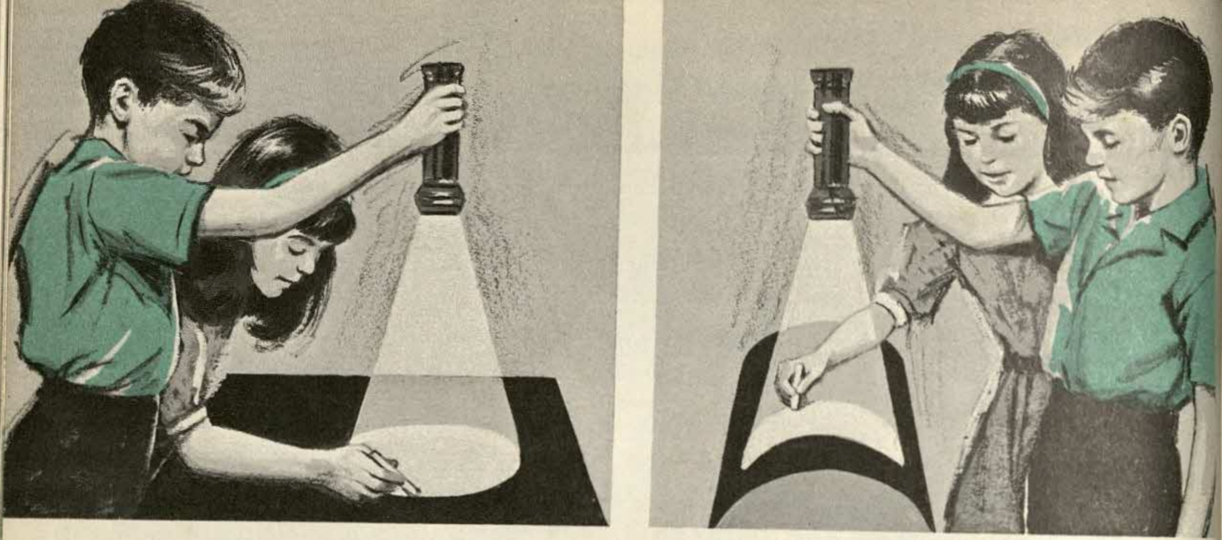
Do your charts help you to forecast temperature? How?

Two students should be assigned to each instrument in your weather station. It should be their responsibility to keep a careful record on the chart for their particular weather element.

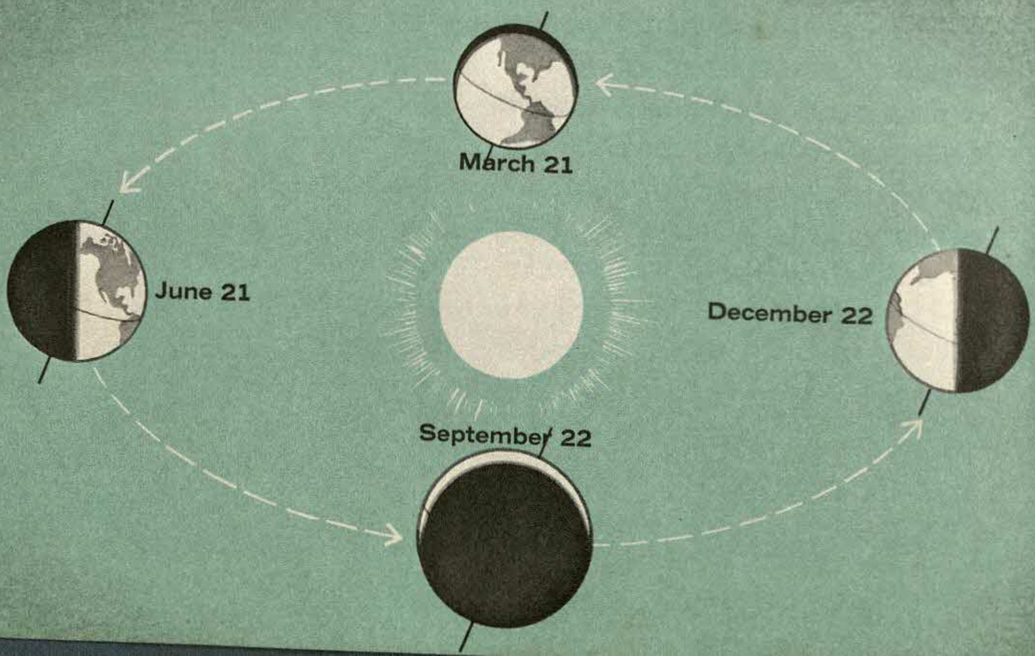
Differences in Temperature on the Earth

Why is it that one day the temperature is 70° and another day 80°? Why is it cold at one time of the year and warm another time? Why is it that Arizona has very warm weather, while northern Canada is cold?

Try these activities to discover some of the answers. Have a notebook ready to write down the results of each activity. First read all of the activity directions carefully. Then record in your notebook what materials you need, what you did, and what you discovered. Sometimes you may find it helpful to use diagrams and drawings in your activity record chart. Line pictures called graphs will help you make predictions.

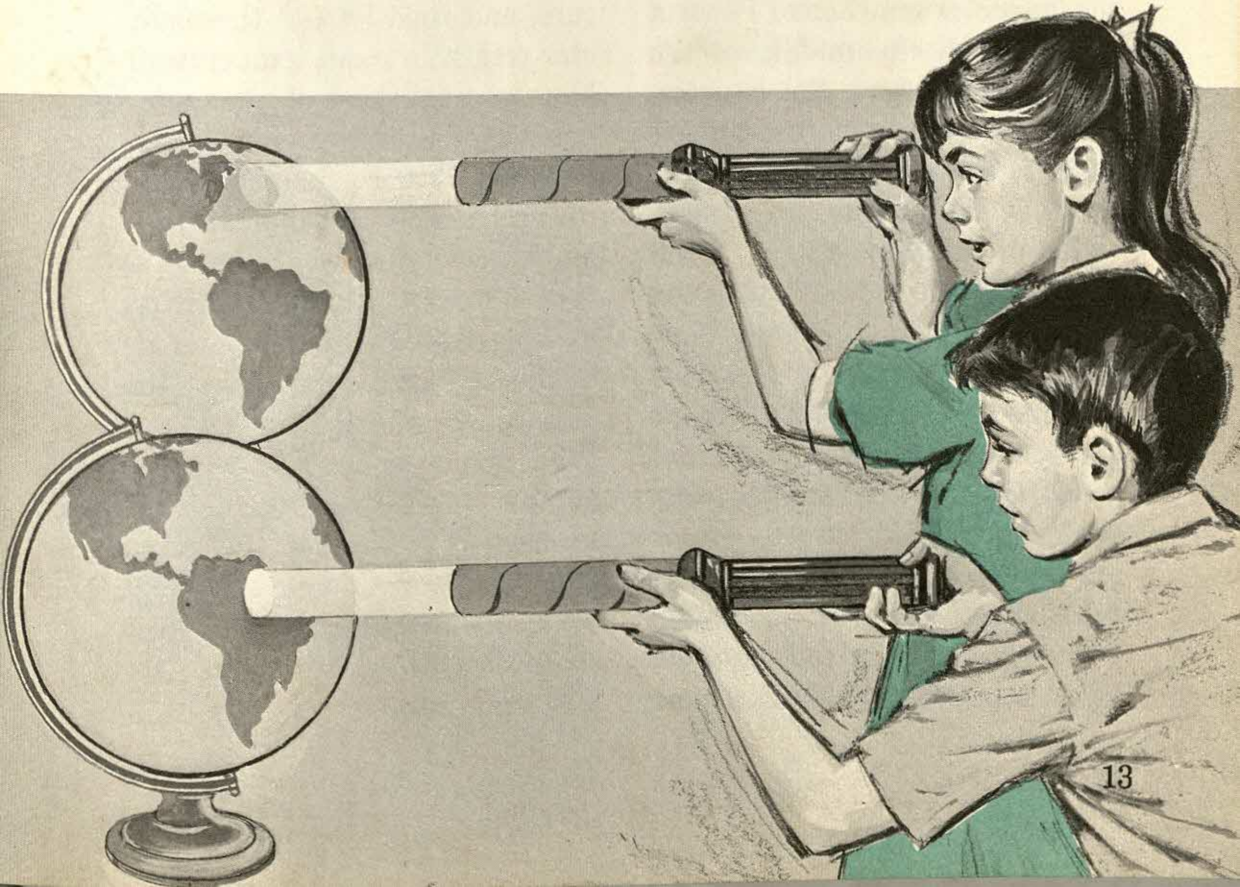


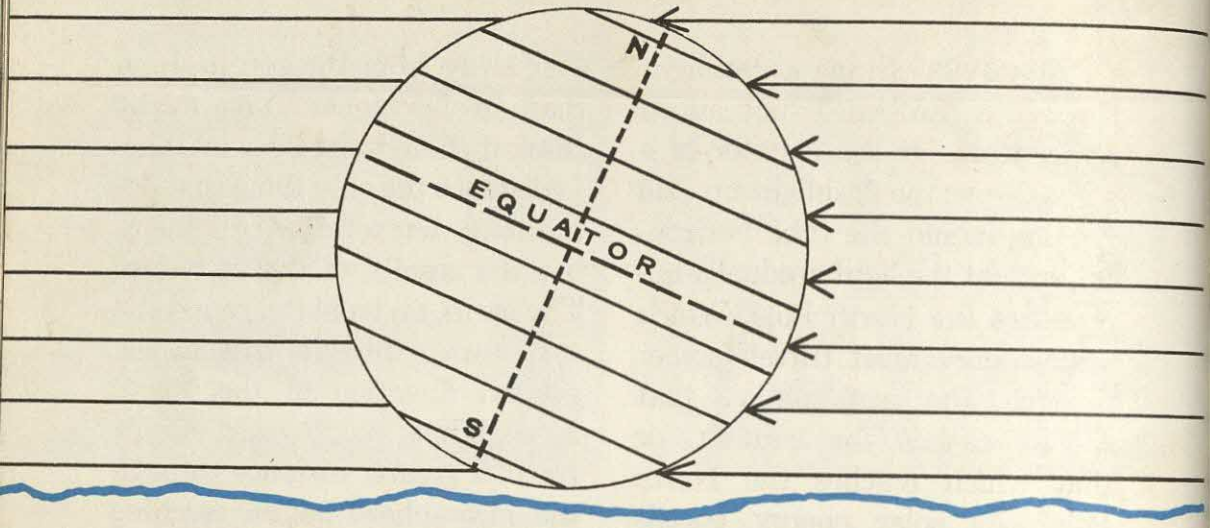
ACTIVITY Place a sheet of heavy, black paper on a table, hold a flashlight slightly above it, and aim the beam directly down on the paper. Have someone draw a chalk mark around the spot of light. Then bend the paper, but hold the flashlight in the same position. Draw around this spot of light. Which spot is larger? Which is brighter? The amount of light was the same in each case. When you bent the paper, the light covered a larger area, and each part of the area received less light than when the beam was direct. Compare the flashlight to the sun and the paper to the surface of the earth. How is the earth's curved surface related to differences in temperature on the earth?



DISCOVER Shine a flashlight through a cardboard tube aimed horizontally at the equator of a globe. Move the flashlight up, still holding it and the tube horizontal, so that the light gradually approaches the North Pole. Which solar energy must travel farther through the atmosphere, that which reaches the equator, or that which reaches the North Pole? As solar energy travels through the atmosphere, more and more radiant energy is lost, and less heat reaches the ground. Will the temperature readings at the North Pole be higher or lower than those at the equator?

Notice that the earth is farther away from the sun in June than in December. You might think it should be colder in June. Is distance the only thing that determines temperature? Remember the results of the activities. The earth, on its path around the sun, always tilts its axis in the general direction of the North Star. When must solar energy travel a greater distance through the atmosphere before reaching the northern hemisphere—June or December? In June the part of the earth on which you live is titled toward the sun. The northern hemisphere receives more solar energy in June that it does in December.

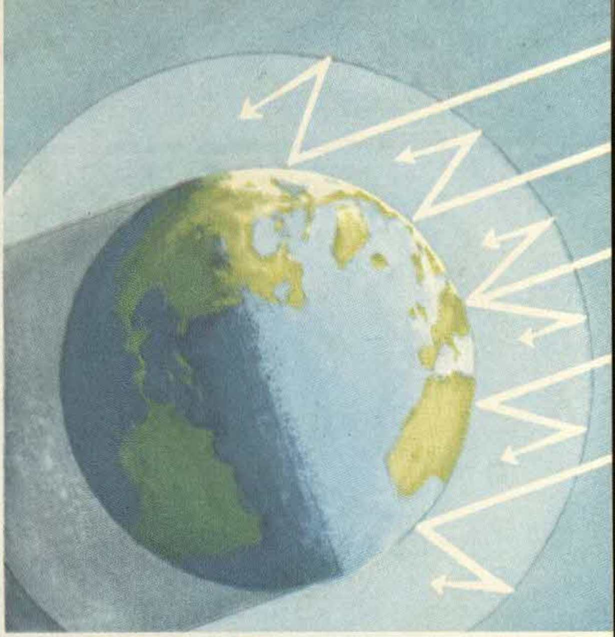




OBSERVE Trace a large circle on a lined page. Cut out the circle. Mark the top of the circle N and the bottom S. N and S mark the North and South Poles of the earth. Think of the lines on the paper as sunbeams. Draw a line through the middle of the circle to represent the equator. Put the circle back in the cut-out space with the North Pole at the top. The lines on the circle match the lines on the paper. Which part of the earth is receiving the most light from the sun? Now move the North Pole to the right as if the earth were titled toward the sun. The earth tilts 23½ degrees. Do the lines match now? Which part of the earth is receiving more light from the sun? Which part less? Move the North Pole to the left. The earth is tilted away from the sun. Which part of the earth is receiving more light from the sun?

COMPARE Hold a thermometer directly beneath a light bulb at a distance of 8 inches for 3 minutes. Record the temperature, and then let the thermometer return to room temperature. Now insert a sheet of newspaper between the bulb and the thermometer. Leave it there for 3 minutes. It is important that the time and the distance be the same as in the first part of the activity. Compare these two temperature readings. How do you think the atmosphere affects solar energy? What do you sometimes see in the air that might lessen the amount of heat that reaches the earth from the sun? Clouds, dust, and other impurities in the air reflect some solar energy. They also absorb some solar energy.

How Atmosphere "Traps" Heat



ACTIVITY Fill a plastic bag half full of soil. Place a thermometer on top of the soil. Tie the bag securely. Place another thermometer on soil outside the bag. Leave both in the bright sunlight for at least 15 minutes. Then record the temperature readings every 10 minutes for a period of 60 minutes. Compare the readings of the two thermometers. Why is it that the soil in the bag is warmer than the soil outside? Both receive the same amount of solar energy, and you might expect them to be at the same temperature. However, solar energy absorbed by the soil in the bag heats up the air confined in the bag; the solar energy is trapped within the bag and keeps the soil warm. The soil outside also heats up the neighboring layers of air, which are free to drift away to other parts of the room. Much of the heat is thus lost. Therefore, the soil in the bag is warmer than the soil outside. ☐☐

The earth is surrounded by an ocean of air called the atmosphere (AT-mus-feer). Some of the sun's energy is turned back by the atmosphere; some is absorbed by the atmosphere; some goes clear through the atmosphere and helps

to warm the earth. The atmosphere, which regulates the amount of the sun's energy that reaches the earth, is very important in making it possible for man to live on the earth. The air around us is warmed from the heat in the earth's surface. The atmosphere slows down the loss of this heat escaping back into outer space.

Have you ever visited a greenhouse? Why is it that, even in winter, flowers bloom in greenhouses? How do all of the following perform the same function: the plastic bag in your activity, the glass roof of a greenhouse, and clouds in the atmosphere?

List reasons why temperature differs on the earth's surface.

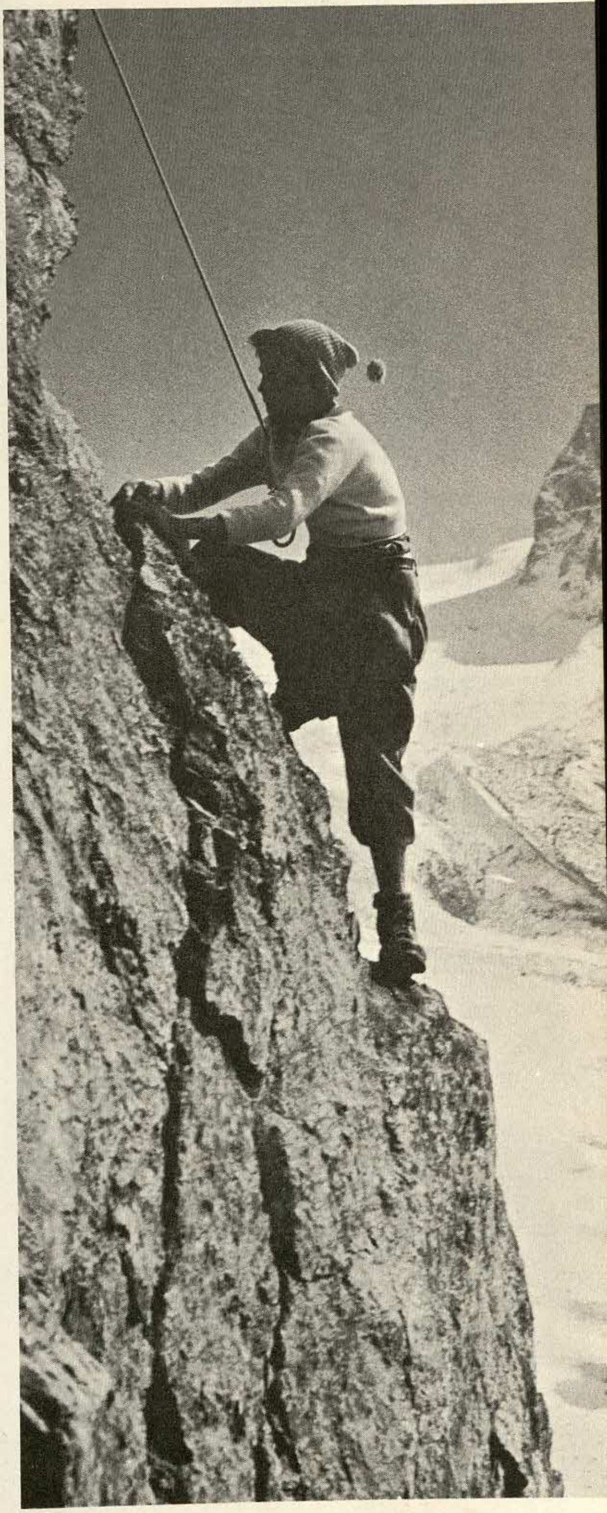
Air Pressure

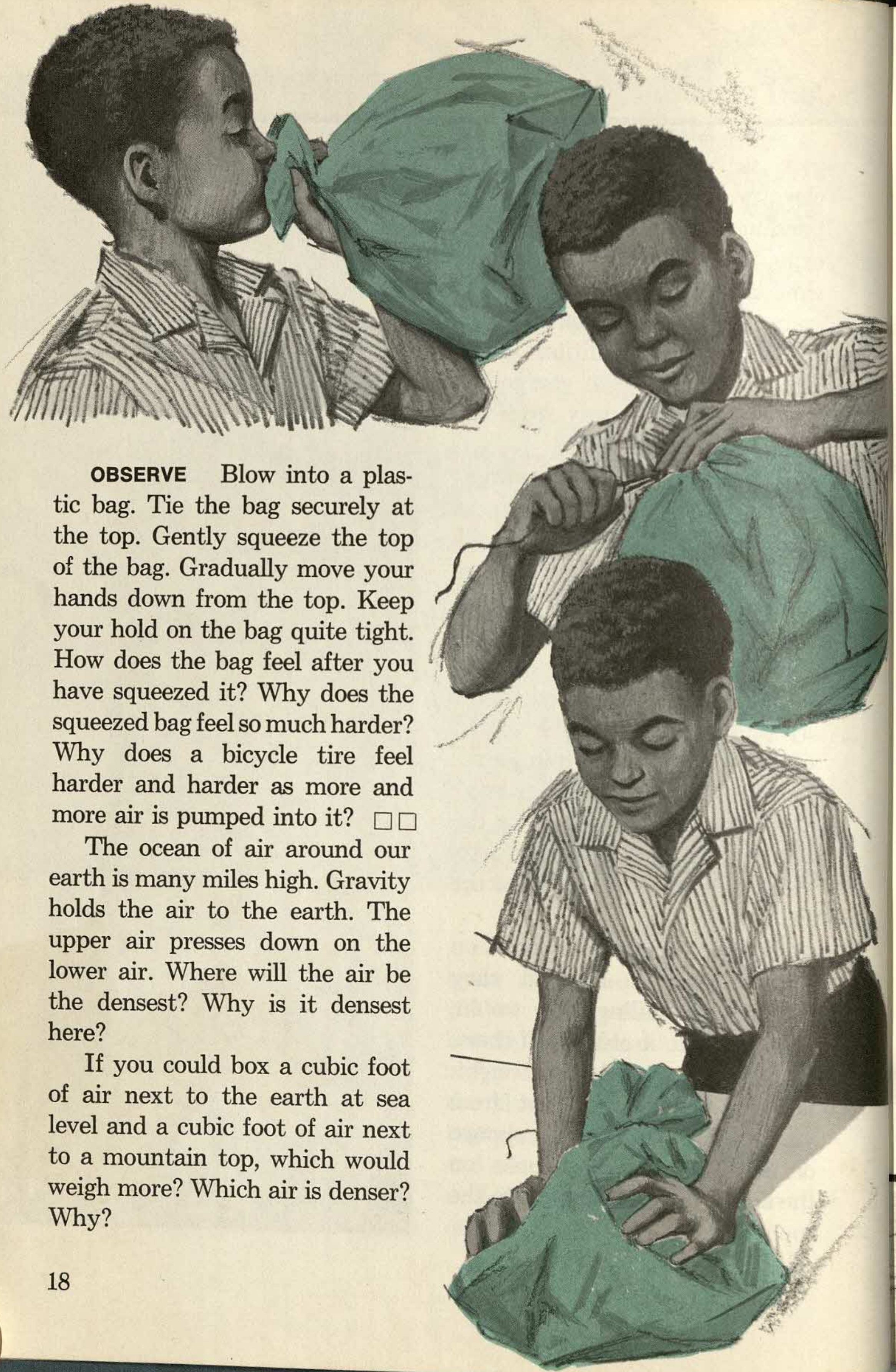
What feeling do you have in your ears when you ride in an elevator to the top of a very tall building? Why do some people experience nosebleeds while traveling in high mountains? Why do many airplanes have pressurized cabins? How do conditions in the atmosphere change as you go farther and farther away from the earth's surface?

In which part of the atmosphere do our weather changes take place? There are other layers of the atmosphere, but we are concerned only with the layer of air next to the earth.

What temperature changes take place as you ascend in the layer of air next to the earth? Why do some mountain peaks have snow on them all year long? Remember that energy from the sun is absorbed by the earth, which is warmed and heats the air.

If you were to pile books on top of your desk until they reached the ceiling, you would, of course, not be able to lift them. Air, like all matter, has weight. How is the air different from your books? Place a flat sponge on a table and pile books on the sponge. What happens to the sponge?





OBSERVE Blow into a plastic bag. Tie the bag securely at the top. Gently squeeze the top of the bag. Gradually move your hands down from the top. Keep your hold on the bag quite tight. How does the bag feel after you have squeezed it? Why does the squeezed bag feel so much harder? Why does a bicycle tire feel harder and harder as more and more air is pumped into it? □□

The ocean of air around our earth is many miles high. Gravity holds the air to the earth. The upper air presses down on the lower air. Where will the air be the densest? Why is it densest here?

If you could box a cubic foot of air next to the earth at sea level and a cubic foot of air next to a mountain top, which would weigh more? Which air is denser? Why?

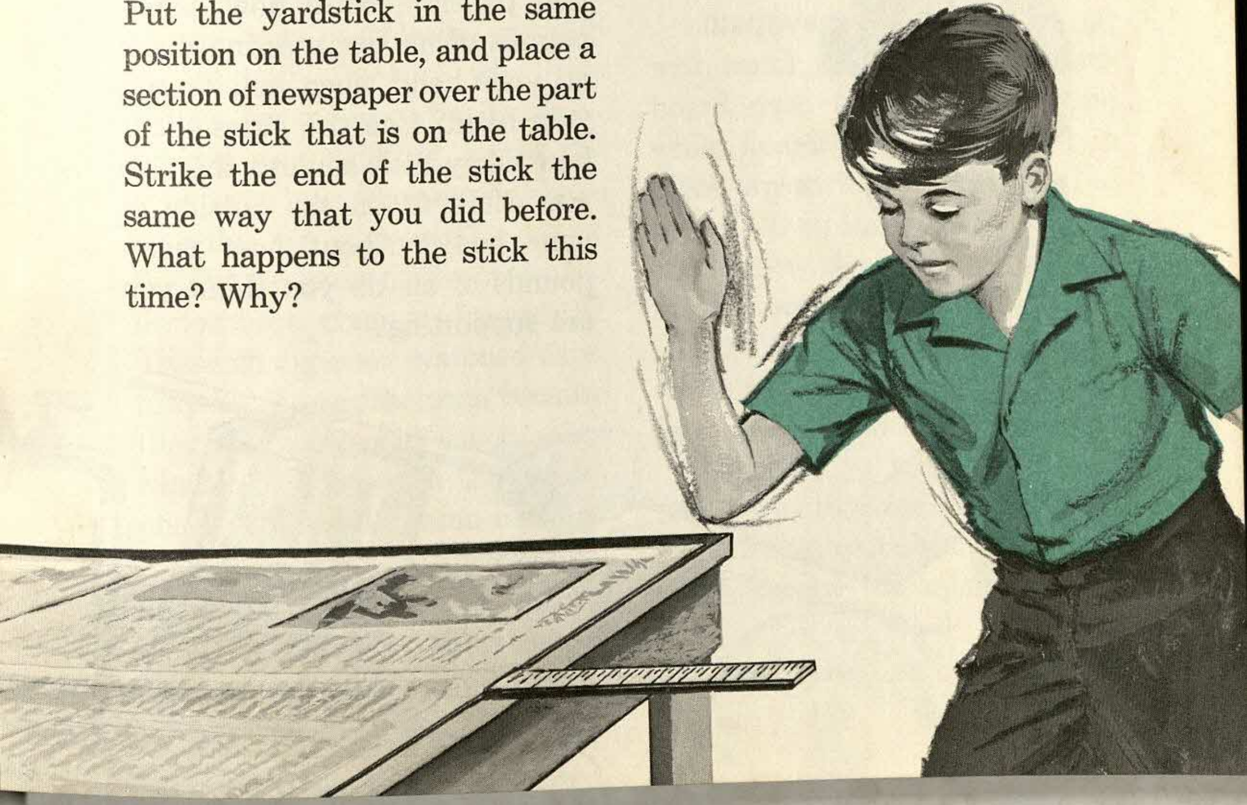
Discovering Air Pressure

ACTIVITY Take a slat from an orange crate (or any very thin piece of wood about 3 feet long and 2 inches wide). Place the slat on a table, allowing about 4 inches to extend over the edge of the table. Then place two double sheets of newspaper over the part of the slat that is on the table. Smooth the papers, leaving no space between the paper and the table. Now strike the end of the slat with a baseball bat. What happens? Why?

ACTIVITY Place a yardstick on a table, allowing about a foot to extend over the edge of the table. Strike the end of the stick with your hand just hard enough to knock the stick off the table. Put the yardstick in the same position on the table, and place a section of newspaper over the part of the stick that is on the table. Strike the end of the stick the same way that you did before. What happens to the stick this time? Why?

Fold the paper into a small bundle, approximately 6″ by 4″. Tape the edges of the folded paper so that the bundle lies flat. Repeat the experiment, using the folded paper. What happens? How do you account for the results of the activity this time?

DESCRIBE Mark off one side of the folded newspaper into one-inch squares. At sea level, the weight of the air on one square inch of your newspaper is about 15 pounds. This weight is referred to as air pressure. On which paper does the air exert the greater force? Why?



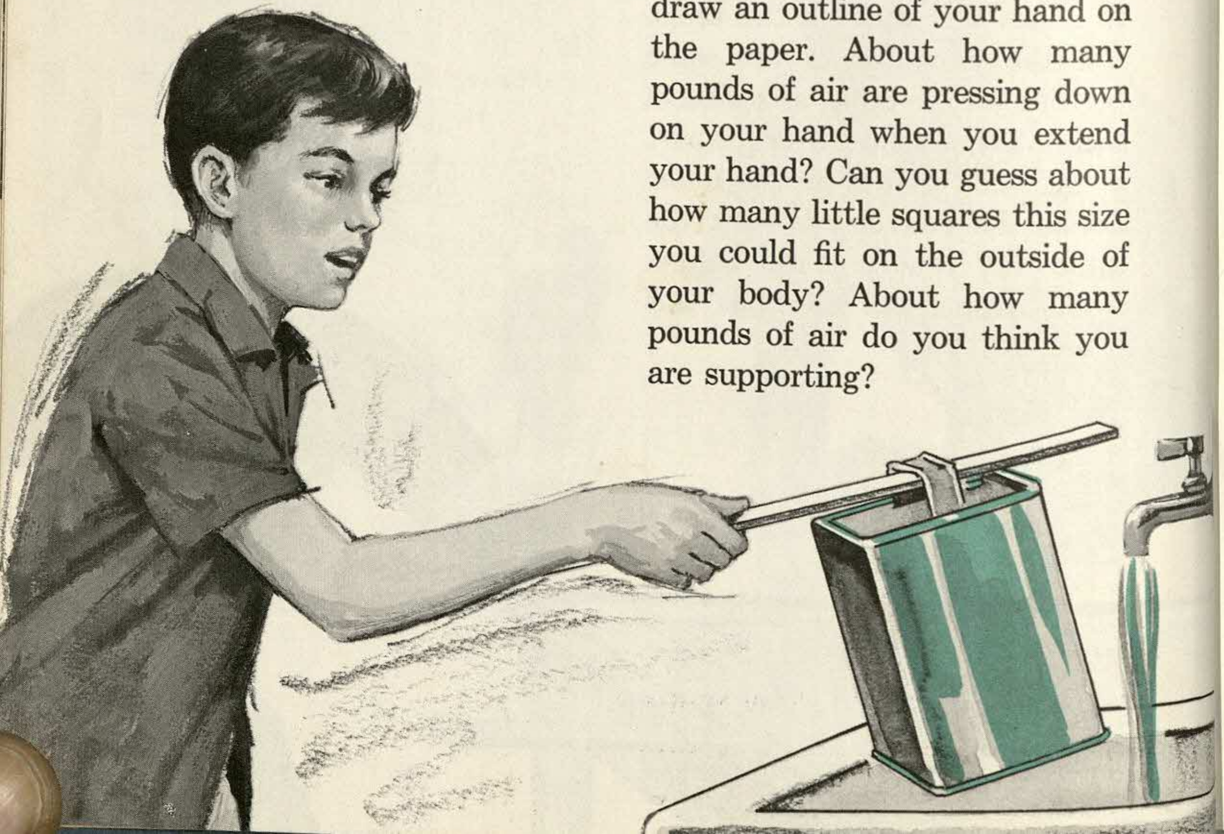
DESCRIBE Fill a glass with water. Place a thin piece of cardboard over it. Very carefully turn the glass upside down. Remove your hand slowly. What happens? Hold the glass sideways. What does this activity tell you about the direction in which air exerts pressure?

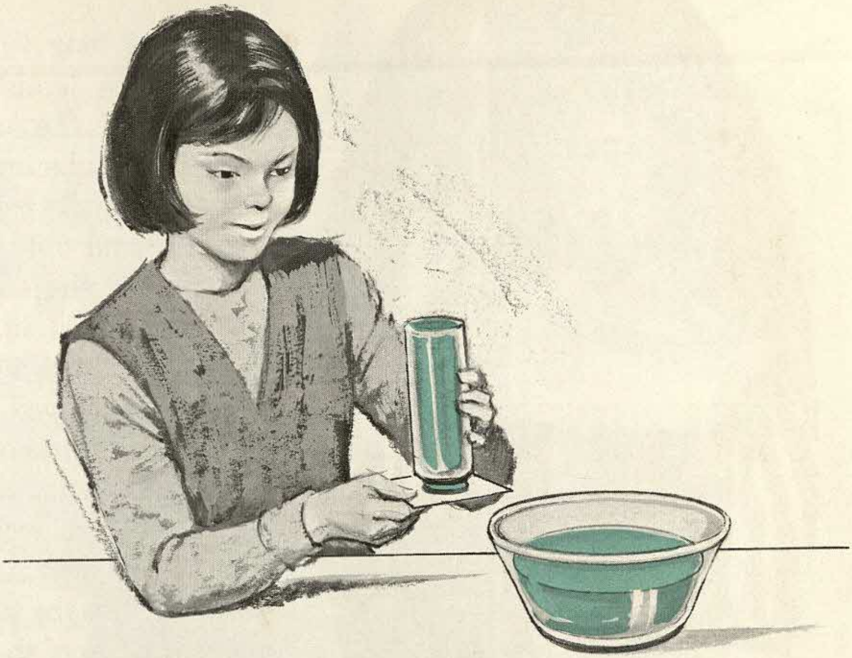
DISCOVER Bring an empty gallon can to school. You may use a maple syrup, varnish, or salad oil can. Be sure that there is no flammable material in the can.

Place a board across the can and have a student stand on either end of the board. Does this crush the can?

Pour about an inch of water into the can and boil the water for about 5 minutes. Remove the can from the stove (caution: It is hot) and place a stopper very tightly in the opening. Let the can cool. You may cool the can faster by holding it under cold water. If you do this, hold the can with a long stick. What happens when the cold water is poured on the can? What is the powerful force that crushed the can? The air outside the can exerted much more pressure than the air within, so the sides of the can collapsed. Why is air pressure outside the can greater than air pressure inside the can? □□

Does air exert pressure on you? Mark off a piece of notebook paper into one-inch squares. Then draw an outline of your hand on the paper. About how many pounds of air are pressing down on your hand when you extend your hand? Can you guess about how many little squares this size you could fit on the outside of your body? About how many pounds of air do you think you are supporting?





Why is it that you usually do not feel air pressure? Is there air inside our bodies? Does the air inside our bodies exert pressure? Can you explain now why some people get nosebleeds in high mountains? Explain why airplanes are equipped with pressurized cabins. What causes the sound you hear when a soda bottle or coffee can is opened?

The pressure of the air in the atmosphere changes frequently. These changes are watched carefully by the weatherman because they indicate to him much about what is happening in the atmosphere. The weatherman uses the term atmospheric (at-mus-FER-ik) pressure. What does this term mean? Changes in atmospheric pressure are signs of changes in weather.

Measuring Air Pressure

DISCOVER Fill an olive jar with water. Place a piece of cardboard over the open end, and while keeping the cardboard in place, invert the jar in a bowl of water. When the open end of the jar is below the level of the water in the bowl, remove the cardboard. What keeps the level of water in the jar higher than the level of water in the bowl? □□

In order to understand how men have answered this question, we must go back in time over 300 years. About the middle of the

S.C.E.R.T., West Bengal
Date 13-1-87
Acc. No. 3714

S.C.E.R.T., West Bengal
Library

seventeenth century, men were bothered by the fact that water from deep wells would rise no more than 32 feet in the tubes of the pumps they were using. An Italian scientist named Evangelista Torricelli (toh-reh-CHEL-ee) (1608-1647) attempted to explain this action of well water. Torricelli believed that air has weight, and he suspected that the pressure of the surrounding air forced the water up the tube of the pump. In order to test this idea, Torricelli filled a glass tube about three feet long with mercury, a very heavy liquid. He put his finger over the open end and turned the tube upside down. He then placed the tube in a dish of mercury and did not remove his finger until the end of the tube was submerged in the mercury.

What do you think happened when he removed his finger? A little mercury ran out of the tube, but a column of mercury about 30 inches high remained in the tube. There was no way for any air to get into the tube. The space above the top of the mercury column is called a vacuum (VAK-yoo-um). What held most of the mercury in the tube?

Mercury is very heavy—more than 13 times as heavy as water. The air at sea level can push just hard enough to balance about 30 inches of mercury in the tube. If the mercury stands higher than 30 inches, what does this indicate about the air pressure? If the mercury sinks lower than 30 inches, what would you conclude about the air pressure?

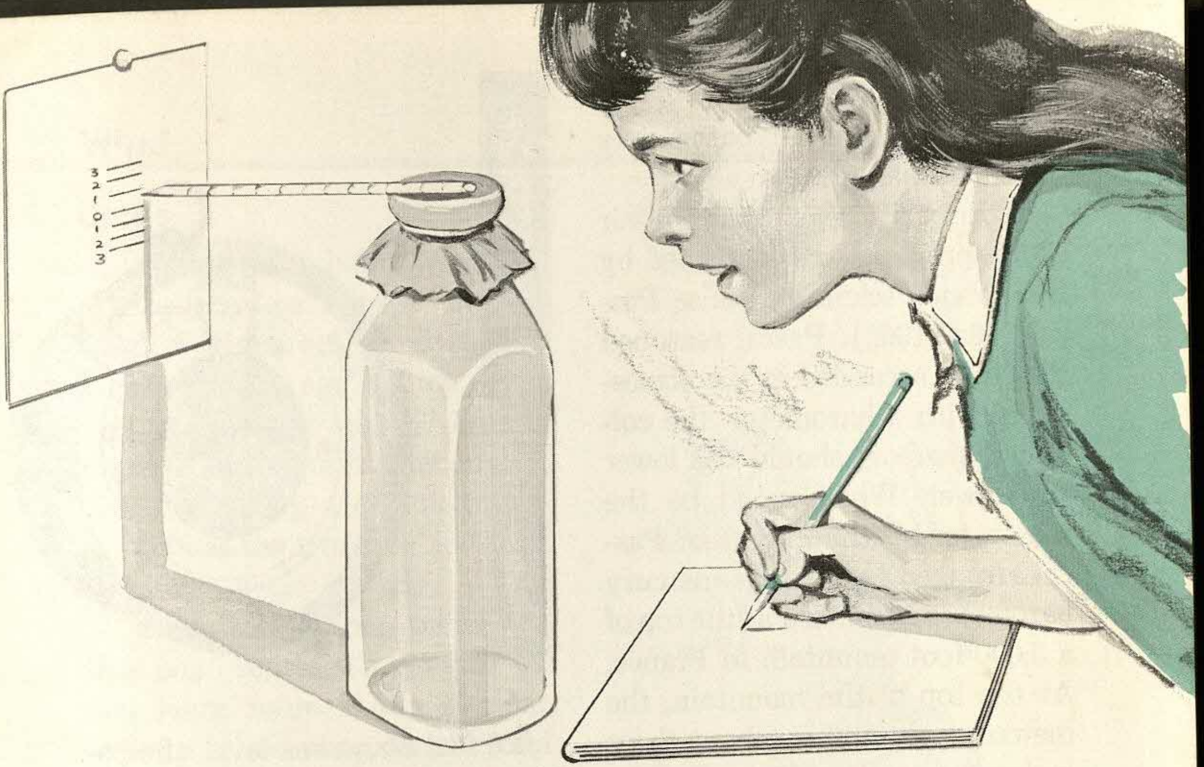
About the same time that Torricelli performed his famous experiment, someone else wondered about the weight of the air. A German mayor named Otto von Guericke fixed a long tube in his house from the first floor through

the roof. The tube, enclosed at the top with a glass dome, contained water and a floating figure of a man. Since von Guericke used water rather than mercury, the tube had to be over 33 feet high—much higher than the tube Torricelli used. The people of von Guericke's town came to see the tube, for it had been recognized that the figure of the man rose higher in the tube when the weather was good and sank when it was stormy. Some people thought that the man caused changes in the weather. Others thought that weather caused changes in the activity of the man. What do you think? Why?

Scientists later began to use the Torricellian tube as a means of noticing changes in the atmosphere. The instrument was called a barometer (buh-ROM-uh-ter). The weatherman uses the barometer to measure air pressure. It is not so important to know what the air pressure reads at the moment; it is important to know whether the air pressure is rising or falling or remaining the same. You hear the weatherman announce the barometric pressure like this: 29.9 and falling. This means that the air pressure is such that it will support a column of mercury 29.9 inches high in the barometer. If the air pressure decreased it could not support as high a column of mercury. The reading would be lower. A decrease in air pressure usually means that unsettled weather is coming. What kind of weather might you expect if you hear that the barometer is at 30.9 and rising?

You can repeat Torricelli's very famous experiment. Your teacher may help you to assemble a mercury barometer.

DISCOVER At home, you can make a simple version of the barometer used by the weatherman. Take a clean, dry milk bottle or orange juice bottle, and place it in warm water for a few minutes. Do not allow any water to enter the bottle. Over the top of the bottle, stretch a piece of rubber from a balloon. Secure it tightly with rubber bands. Glue a soda straw to the rubber top so that the straw extends horizontally from the center. Hold the straw firmly against the glue until it dries. Flatten the free end of the straw by pinching it. Put a piece of paper behind the straw. Be sure that the instrument is not near a radiator or in the direct sunlight. Look at the picture. Put a mark on the paper, level with the straw. Mark this spot 0. At ⅛ inch intervals, mark 1, 2, and 3



above and below the 0. If the air pressure increases, in what direction will the straw move? If the air pressure decreases, what will happen to the level of the straw? Why does the straw move in this way? Remember, there is air inside the bottle. Why isn't your barometer as accurate as the one used by the weatherman? Record changes in air pressure on your chart. Can you discover any relationship between changes in barometer reading and changes in the weather? ☐☐

You may be familiar with the kind of barometer that is a round metal container, and looks something like an alarm clock. Pressure changes on the sides of the container cause the pointer on the face of the barometer to move. This is called an aneroid barometer. The weatherman usually relies on an aneroid barometer. Your milk bottle barometer is a simple aneroid barometer.

Some aneroid barometers make a continuous recording of the air pressure on a revolving

AIR PRESSURE

Week of ______________

	A.M.	*P.M.*
Monday	Rising	Falling
Tuesday		
Wednesday		
Thursday		
Friday		

drum. Such aneroid barometers are called barographs.

Torricelli's belief that the air exerts pressure was confirmed by the French scientist, Blaise Pascal (1622-1662). Pascal reasoned that if he ascended in the atmosphere with a barometer, the column of mercury should sink lower and lower. What would be the reason for his thinking this? Pascal arranged to have the mercury barometer assembled at the top of a 3,000-foot mountain in France. At the top of the mountain, the mercury column was about three inches lower than it was at the foot of the mountain. For every 1,000 feet above sea level, the barometer reading is about an inch less. How could a barometer be used to determine altitude above sea level?

The mercury barometer is more accurate than the aneroid barometer. The aneroid barometer is more widely used. Why do you think this is so?

Listen to the weather report each day at a certain time. Keep a record of the barometric reading and the average temperature for each day over a period of one week. Study your record at the end of the week. Do the temperature and atmospheric pressure increase together? Do you think that one affects the other? Why?

Check your answers by keeping your record for a longer time.

Wind

Cycles

You have probably tried—unsuccessfully—to answer the old riddle, which came first, the chicken or the egg. Which comes first, summer or winter? Day or night? Any action that makes changes during a complete trip, but makes the trip over and over, is called a cycle (SY-k'l).

Explain how each picture on this page represents a cycle. As you learn more about weather, look for other examples of cycles.

What Causes Wind?

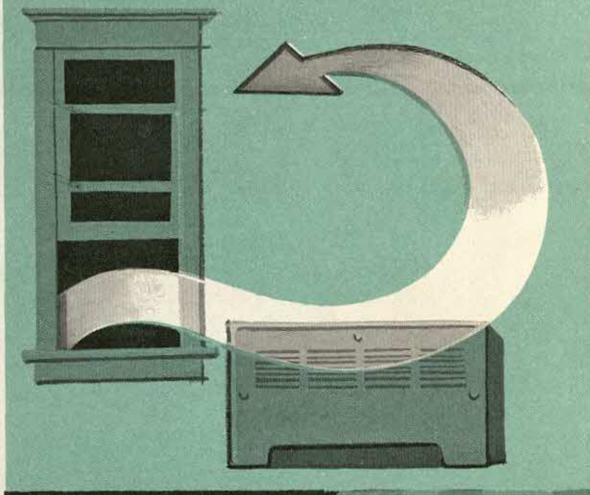
MEASURE Fill one coffee can with dry soil and another with cool water. Place both cans outdoors in the sunshine, and put a thermometer in each can. After two hours, check the temperatures. Which is warmer, the soil or the water?

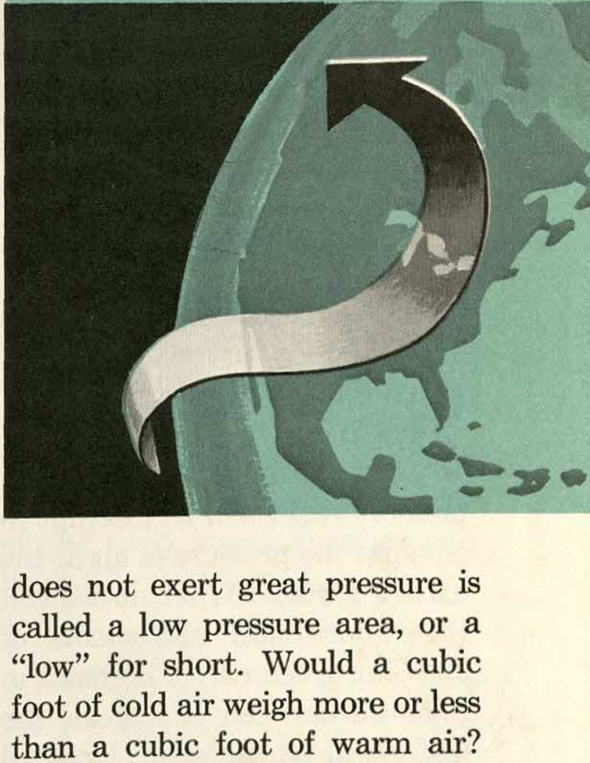
After a summer rain, when the sun has been shining long enough to warm the pavement, have you ever walked barefoot through a puddle? Which was warmer, the puddle or the sidewalk?

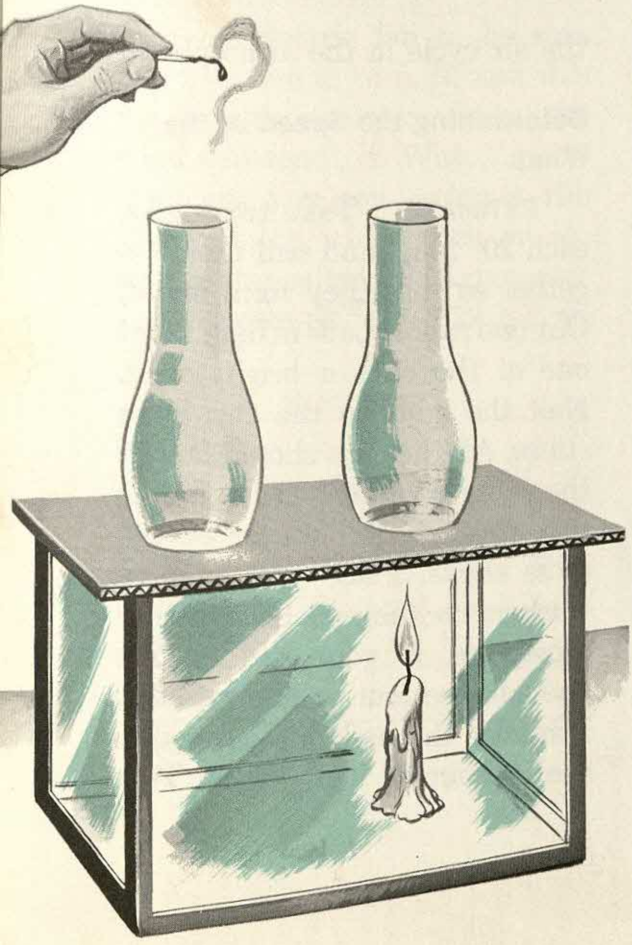
On a hot, sunny day at the beach, which do you think is warmer, the sand or the water? Which gets hotter more rapidly, land or water? Does the sand remain hot for very long after the sun sets? Are the temperatures of the water at night and during the day very different? Which do you think gets cooler more rapidly, land or water?

DESCRIBE For the following activity you will need a glass aquarium, two glass kerosene-lamp chimneys, a piece of cardboard large enough to cover the top of the aquarium, a short candle, and a few matches. Cut two circles in the cardboard, just large enough to hold the chimneys. Place the candle in the aquarium, light the candle, and cover the aquarium with the cardboard. Insert the chimneys through the cardboard, as you see in the picture. Be sure the candle is directly underneath one of the chimneys. Light a match and blow it out. Then hold the smoking match above the chimney which is farther from the candle. In what direction does the smoke travel? Why? □□

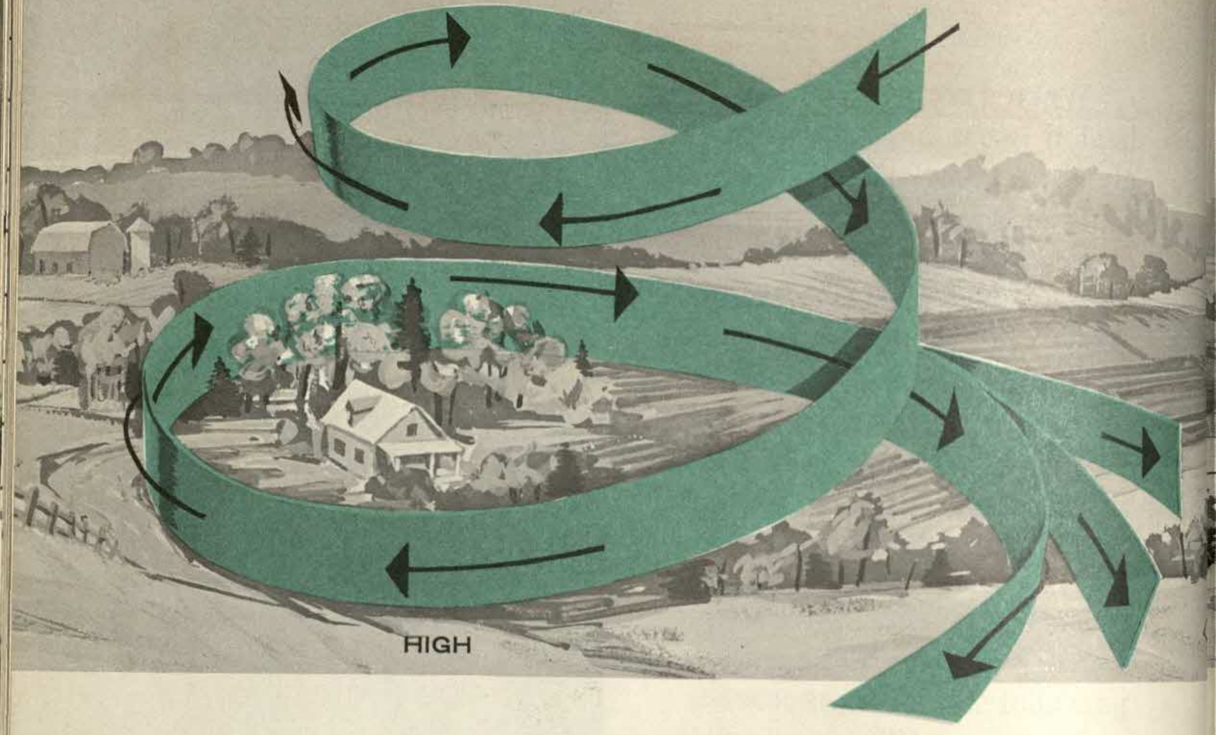
When a section of the earth is heated, what happens to the air above that part? What causes currents in the air? Why are these currents called convection currents? When a mass of air rises above the earth, what change takes place in the air pressure near the earth? A rising mass of air creates a current which is referred to as an updraft. A portion of the atmosphere where the air does not exert great pressure is called a low pressure area, or a "low" for short. Would a cubic foot of cold air weigh more or less than a cubic foot of warm air? What do you think is meant by the term "downdraft"? What do you think is meant by the term "high"?







Meteorologists refer to lows as "cyclones" and highs as "anticyclones." What changes in the

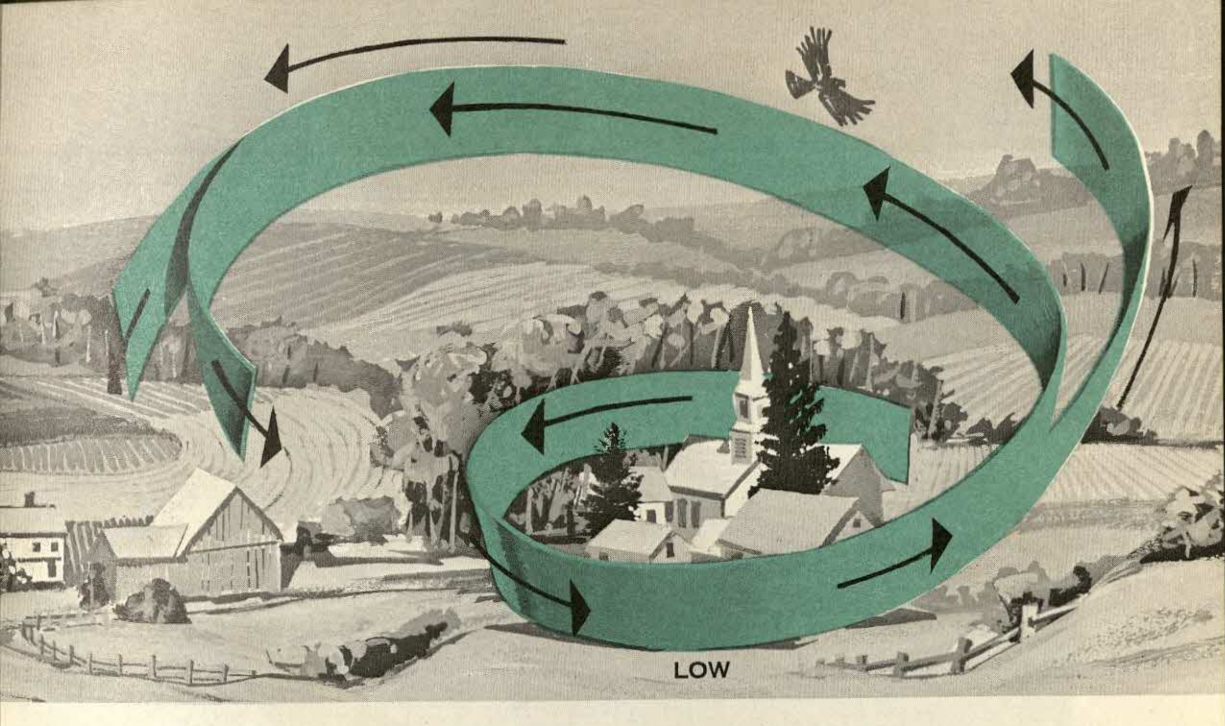


barometer occur when a high moves into your neighborhood? When a low moves in?

When warm air rises, cooler air flows horizontally from high pressure regions in an attempt to equalize the pressure of air at the earth's surface. What do we call these horizontal movements of air? The greater the difference in pressure between two areas, the faster will be the wind. Unequal air pressure causes wind. What causes unequal air pressure? Does air move through your kerosene-lamp chimneys in a cycle? Does air in the atmosphere move in a cycle? What causes the air cycle in the aquarium? What causes the air cycle in the atmosphere?

Determining the Speed of the Wind

ESTIMATE Take two sticks, each 20″ long, and nail them together so that they form an ×. Cut two rubber balls in half. Paint one of the cups a bright color. Nail the cups to the two cross sticks. All the cups should face in the same direction. Drive a long nail through the center of the cross sticks. Place two or three washers on the nail beneath the crosspiece. If your nail is long enough, use four or five washers. Hammer the nail into a wooden shaft about 15 inches long. Test

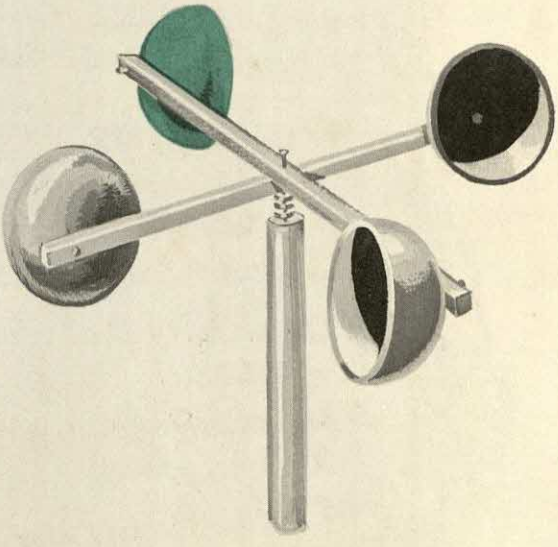


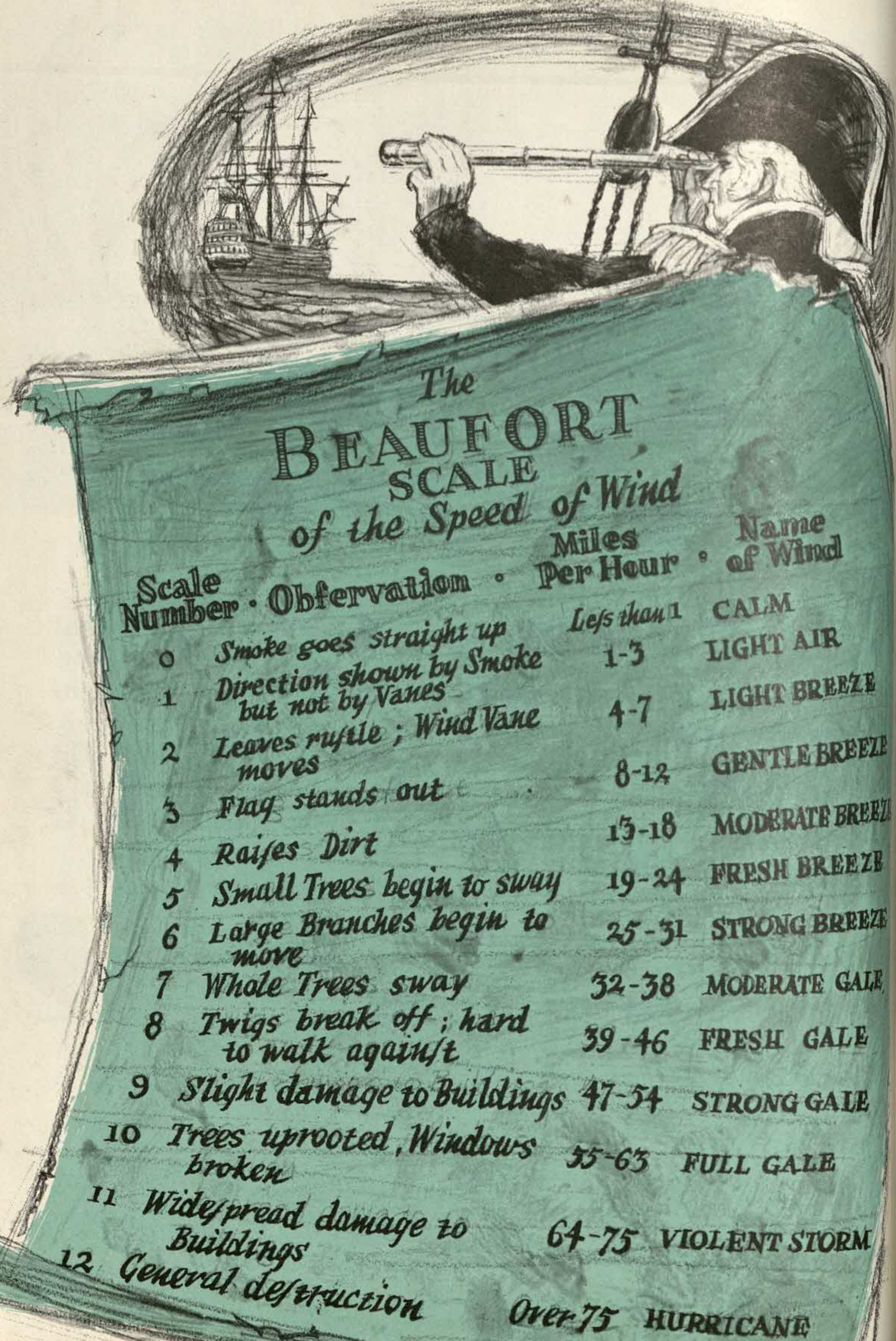
with an electric fan to be sure the ✕ is free to turn. Mount this instrument outdoors where the wind can reach it. With this instrument you can estimate the speed of the wind. Such an instrument is called an anemometer (an-uh-MOM-uh-ter). To get an approximate estimate of the speed of the wind, do the following. Count the number of turns the painted cup makes in 30 seconds. Divide this number by 5. The answer will be a rough estimate of the wind speed in miles per hour.

WIND SPEED

*Week of*__________________

	A.M.	*P.M.*
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		





The BEAUFORT SCALE of the Speed of Wind

Scale Number	Obſervation	Miles Per Hour	Name of Wind
0	Smoke goes straight up	Leſs than 1	CALM
1	Direction shown by Smoke but not by Vanes	1-3	LIGHT AIR
2	Leaves ruſtle ; Wind Vane moves	4-7	LIGHT BREEZE
3	Flag stands out	8-12	GENTLE BREEZE
4	Raiſes Dirt	13-18	MODERATE BREEZ
5	Small Trees begin to sway	19-24	FRESH BREEZE
6	Large Branches begin to move	25-31	STRONG BREEZE
7	Whole Trees sway	32-38	MODERATE GALE
8	Twigs break off ; hard to walk againſt	39-46	FRESH GALE
9	Slight damage to Buildings	47-54	STRONG GALE
10	Trees uprooted, Windows broken	55-63	FULL GALE
11	Wideſpread damage to Buildings	64-75	VIOLENT STORM
12	General deſtruction	Over 75	HURRICANE

You can get a good idea of the speed of the wind without an anemometer by using the scale of wind force developed in 1805 by Admiral Beaufort (BO-fert) of the British Navy. This scale is called the Beaufort scale.

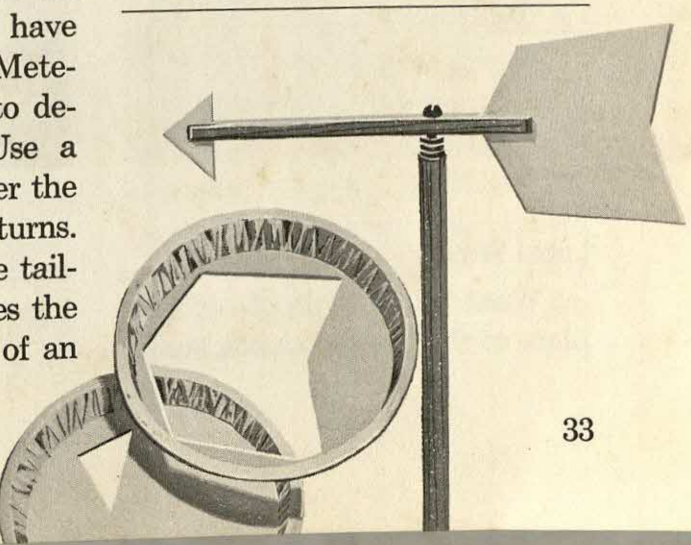
Determining the Direction of the Wind

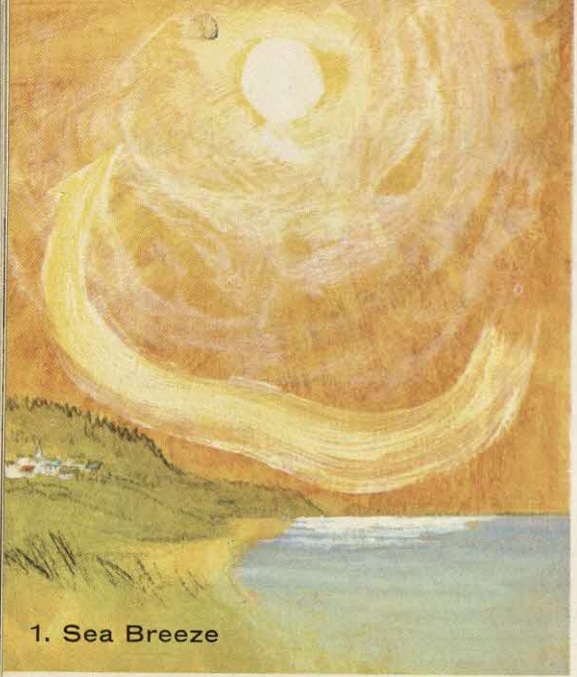
DISCOVER Cut pieces from aluminum pie plates as shown in the picture. Cut a notch about 1″ deep in each end of a dowel stick. Insert the aluminum pieces in the notches, and glue them in place. Find the point along the stick where it balances. Hammer a nail through the stick at this point, and place two or three washers on the nail beneath the stick. Hammer the nail part way into a wooden shaft about 15″ long. Hold the shaft, and blow the tailpiece to make sure that the arrow is free to spin. Mount the arrow outside on a post or fence where winds blowing from all directions will hit it. You have constructed a wind vane. Meteorologists use wind vanes to determine wind direction. Use a compass to help you discover the direction your wind vane turns. When a north wind hits the tailpiece, in what direction does the arrow point? If you speak of an east wind, in which direction should you turn to feel the wind in your face? The direction of the wind is the direction *from* which the wind blows. When an east wind blows, in what direction does the wind vane point? From what direction does a northerly wind blow?

Record wind direction on a chart twice a day. Record the appearance of the sky as clear, cloudy, partly cloudy, or rain. After a week, note if there seems to be any relationship between the direction of the wind and the kind of weather that occurs.

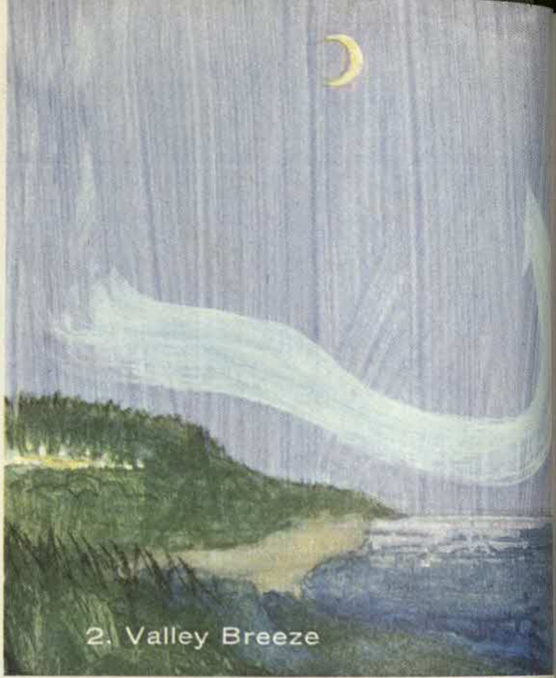
WIND DIRECTION

Week of ______	*A.M.*	*P.M.*
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		

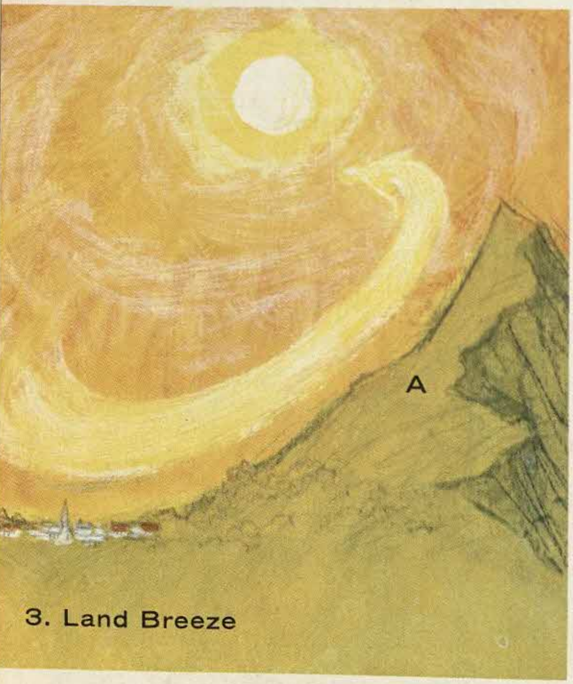




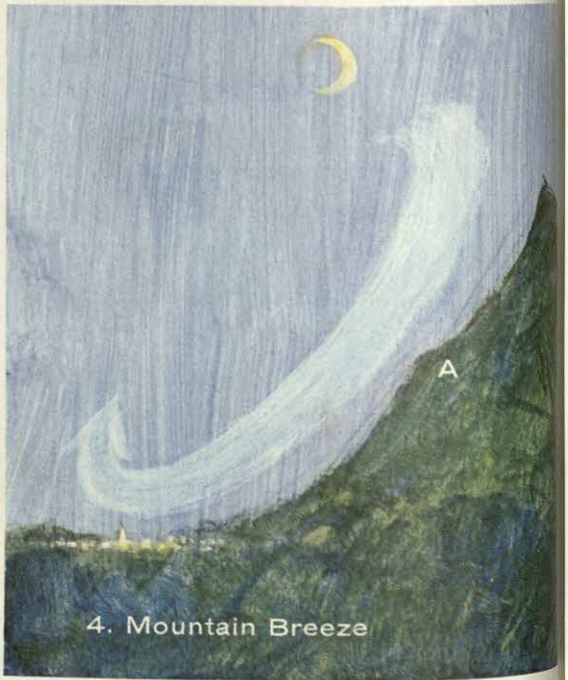
1. Sea Breeze



2. Valley Breeze



3. Land Breeze



4. Mountain Breeze

Local Winds

What movements of air take place at the beach on a hot, sunny day? Look at picture 1. Which becomes warmer faster, the land or the water? What happens to the air over the land? In what direction does it move? What happens to the air over the water? Explain why, at the shore, a cool breeze often blows from over the water during the day.

Look at picture 2. At night, which gets cooler more slowly, the land or the water? In which direction would you expect the breeze to blow at night? Why? A wind is always named according to the place where it *starts*. In what direction does a land breeze blow? a sea breeze?

Look at picture 3. When the sun shines on a mountain slope, the air near the surface of the mountainside is heated. What happens to the mass of air at *A*? Why? When the cooler air rushes in to replace the warmer air, a valley breeze is begun. Study picture 4 and tell how a mountain breeze originates.

Planetary Winds

The winds that you have learned about so far are all local winds, which are also called "variable" winds. These local winds are all a part of a vast system of winds that blow over large areas of our planet. The winds in this system are called planetary (PLAN-eh-*tayr*-ee) winds. Planetary winds, like local winds, move in cycles, creating updrafts, high winds, downdrafts, and low winds.

Very little is known about the movement of air in the upper atmosphere. However, a region of very strong wind currents 30,000 to 40,000 feet above the earth's surface has recently become recognized. These winds travel mainly from west to east, and move in a way which is very similar to currents in the ocean. They are called jet streams. Airplane pilots can sometimes locate and fly with jet streams, using the thrust of these winds to increase flying speed.

At the equator, warm air rises. What kind of draft is formed? There are regions on either side of the equator called doldrum belts. At the doldrum belts the air is very still because of the constant updraft. Why were the doldrum belts feared by sailors in the early days of sailing vessels? Have you ever heard someone use the expression "in the doldrums" to describe a tired, depressed feeling? Explain this expression.

Cool air near the earth's surface moves from north and south toward the equator to replace the warm air that rises and moves away from the earth's surface. The winds created in this way are called trade winds.

EXPLORE Spin a globe in a counterclockwise direction, as viewed from above the North Pole. With a china-marker (wax pencil), try to draw a straight line on the spinning globe from 35°N latitude to the equator. Do not press very hard with the china-marker. Stop the globe. What is the direction of the line?

Look at the map of wind belts in the northern hemisphere. Notice that the winds curve. We say that winds are "deflected" to the right in the northern hemisphere. In what direction do the trade winds in this hemisphere blow? What do we call the movement of the earth that causes winds to be deflected?

The warm air that rises over the equator separates at high altitudes into two sections, one moving north and the other south. At about 30° latitude this air has become cool enough to settle to earth again. The downdraft creates a high near the surface of the earth. On the ocean, this zone is referred to as the "horse latitudes." It is said that crews whose sailing ships were becalmed in this region threw horses overboard in order to lighten the load of the vessels. Can you account for the unusually calm winds in the zone of the horse latitudes?

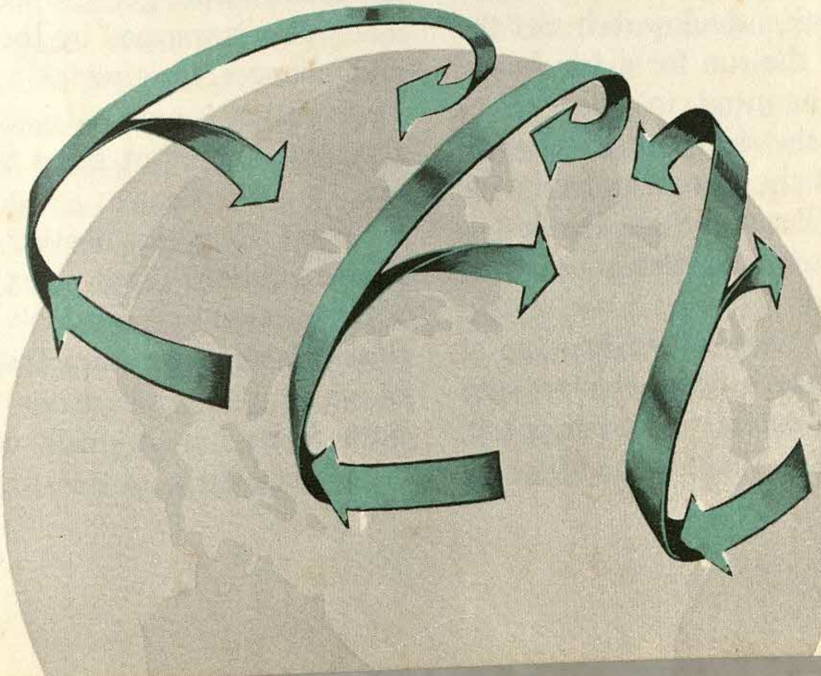
ACTIVITY Spin your globe in a counterclockwise direction again. This time, try to draw a straight line from 30°N latitude to the Arctic Circle.

The planetary winds that blow between 30°N latitude and the Arctic Circle are called westerly winds, or westerlies. In what direction are the westerlies deflected? Explain why these winds are called westerlies. How do westerly winds help the weather forecaster? Why is it that weather conditions in Chicago can often be used to forecast weather in New York? Why are easterly winds in the United States often a sign of unsettled weather? □□

Remember that planetary winds can be influenced by such local conditions as mountains and large bodies of water, and are seldom as easy to predict as the diagram might lead you to believe.

You have seen how all winds move in a cycle. Because of the rotation of the earth and unequal heating of the earth's surface, winds also swirl in spirals as they move through the cycle. In highs and lows, air moves in spiral patterns as well as in vertical patterns. Have you ever seen air swirl around like a whirlpool of water? The air in the lower atmosphere is whirling around, sweeping up and down. Watch how papers, dust, and leaves are moved by the wind. Watch how wind moves tree branches, the flag, and clothes on the line. Later in this unit you will learn that the swirling movement of air in unusual highs and lows is one reason for storms.

Winds move in the atmosphere with energy equal to nearly 7,000 atomic bombs. The daily energy of winds on the earth exceeds all the electric power the United States could produce in 100 years! It is difficult to imagine the tremendous displays of force and unrest that recur daily above the earth's surface.



Moisture

Evaporation

OBSERVE Wet two sections of the blackboard. Fan one section with a piece of cardboard or an electric fan. Which section dries faster? Why do clothes dry fast on a windy day?

DESCRIBE Pour a little water into a wide, shallow dish. Set the dish in the sun for a few hours. What happens to the water? Would the same thing happen if you left the dish of water in the house? Try it and see. Do clothes dry faster on a sunny day or a cloudy day?

COMPARE Pour one cup of water into a wide, shallow dish and one cup of water into a tall, narrow jar. Place both in the sun. From which container does the water disappear more rapidly? How can you tell?

TEST Soak some pieces of wool and cotton in water, and place them in the sun. Both materials should be about the same size. Which dries faster? □□

How does water in rivers, lakes, and oceans get into the air? The water is warmed by the sun, and changes into water vapor. Water vapor is a gas. It is one of the most important gases in the air.

What effect does heating have on evaporation? What effect does wind have on evaporation? How does temperature affect the rate of evaporation? Does water evaporate faster from a small surface or from a large surface? Does

water evaporate at different rates from different objects? How can we explain this?

COMPARE Fill a flower pot with soil, and pour water into the soil until water begins to drip from the bottom of the pot. Weigh the flower pot. Do not water it again. Weigh the flower pot each day for a week. Is there a difference in the weights? What caused this difference? Water evaporates from soil as well as from bodies of water. □□

What do we call the tiny particles that make up all solids, liquids, and gases? When a liquid changes to a gas, a change in molecular activity takes place. Remember that all molecules are in motion. What effect does heat have on the molecules of water? Heat is a form of energy. The more energy they have, the faster and farther the molecules move. The molecules of a gas move more freely and faster than those of a liquid. What happens when a liquid disappears into the air? Explain. What is this change from a liquid to a gas called?

Saturation

DESCRIBE Wet a piece of cloth, and then wring it out so that no water drips from it. Place the cloth in a pan and drip water, a few drops at a time, on the cloth. Does the cloth soak up the water? Keep adding water. What finally happens? When an object has absorbed all the water it can hold, we say that the object is saturated (SACH-er-ayt-ed). □□

Each day millions of tons of water are changed to water vapor. Is there any limit to the amount of water vapor the air can hold?

Condensation

ACTIVITY Fill a shiny can with ice cubes. Add some cold water, and stir the ice water for a couple of minutes. What happens on the outside of the can? Where do the droplets of water come from? Fill another shiny can with hot water, and stir for a couple of minutes. What happens this time? □□

When air is saturated, it contains all of the water vapor it can hold. When water vapor changes to water, we say that condensation (kon-d'n-SAY-sh'n) takes place. What must be the condition of air before condensation can take place? What happens when saturated air is cooled? How does temperature affect the rate of condensation?

COMPARE Chill a dry, clean jar, and hold it close to steam from a teakettle. Record the length of time required before droplets fall from the jar.

Take another clean, dry jar, and warm it slightly. Hold this jar close to the steam at the same distance from the teakettle. Record the time required before droplets fall from the jar. Compare the two lengths of time. □□

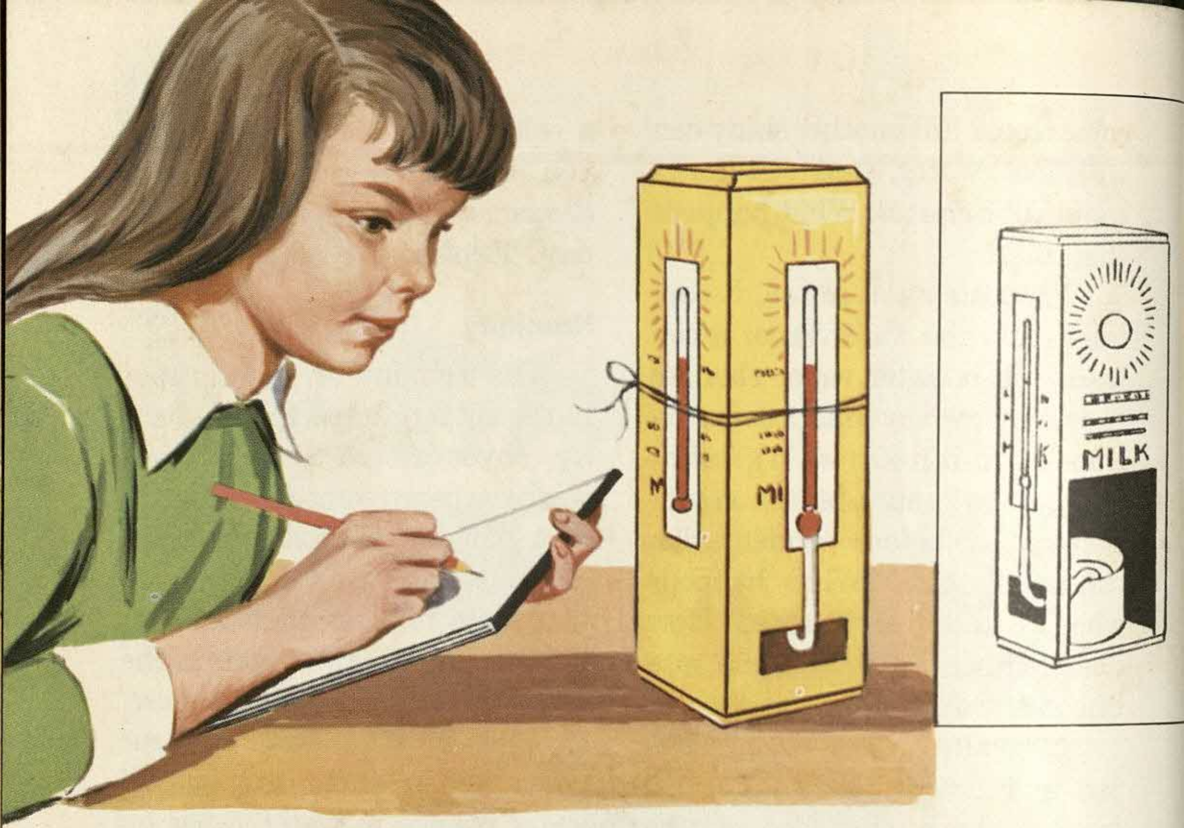
Which do you think can hold more water vapor, one cubic foot of warm air or one cubic foot of cold air? If air is chilled, what is likely to happen to the water vapor in the air?

Explain why droplets of water appear on the outside of a chilled pitcher of lemonade. What causes car windows to "steam over"? On a cold day, what happens when you breathe on a window? Does the same thing happen on a warm day? Explain the difference.

Humidity

The amount of water vapor in the air is referred to as humidity (hyoo-MID-uh-tee). Perhaps you have heard someone complain on a hot day, "It isn't the heat, it's the humidity." Why is it that you may feel uncomfortable if there is much water vapor in the air? On a hot day you perspire. Droplets of water form on your body. When these droplets of water change to water vapor by evaporation, they leave your skin cooler. If the air is almost saturated, what happens to the perspiration on your body? Why does this leave you uncomfortable?

The weatherman is interested in knowing the amount of water vapor in the air compared with the amount the air can hold at a particular temperature. He calls this comparison the "relative humidity." When the weatherman says the relative humidity is 60%, he means there is six-tenths (6/10) as much water vapor in the air as there could be at that temperature. How would you describe the condition of the air if the relative humidity is 100%?



DISCOVER Attach two identical thermometers to a milk carton, as shown in the picture. Cut the tips off of a clean, white cotton shoestring. Slip the bulb of one thermometer into one end of the shoestring. Let the other end of the string rest in a small container of water that is inside the milk carton. Each day record the readings on both the "wet" and "dry" thermometers. This weather instrument is called a hygrometer (hy-GROM-uh-ter). It is used to determine relative humidity. Your wet-and-dry-bulb thermometer is a common type of hygrometer. The weatherman uses hygrometers which are more accurate than yours, but you can determine high and low humidity with your wet-and-dry-bulb thermometer. Use this as a guide: record a difference in temperature of 15 or more degrees as "low";

HUMIDITY

*Week of*______________

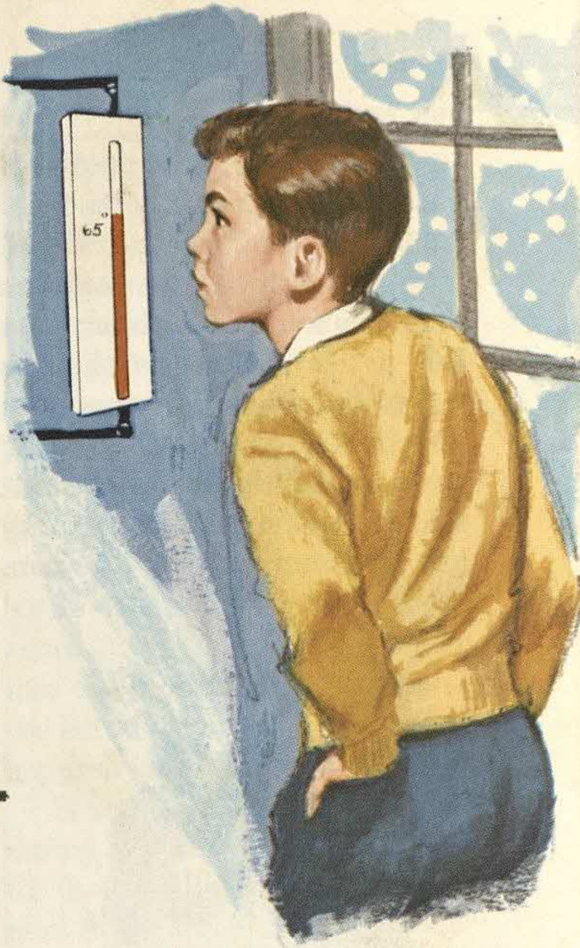
	Wet Bulb	*Dry Bulb*	*Humidity*
Monday	70°	80°	High
Tuesday	63°	80°	Low
Wednesday			
Thursday			
Friday			

record a difference of less than 15 degrees as "high."

If the difference between the two thermometers is high, why is the humidity low?

You know that when a liquid evaporates from a surface it leaves the surface cooler. If the wet bulb reading is much lower than that of the dry bulb, what is happening to the water on the shoestring? Is the humidity high or low? Explain your answers.

If there were little difference between the two thermometer readings, what conclusion would you draw? Why?



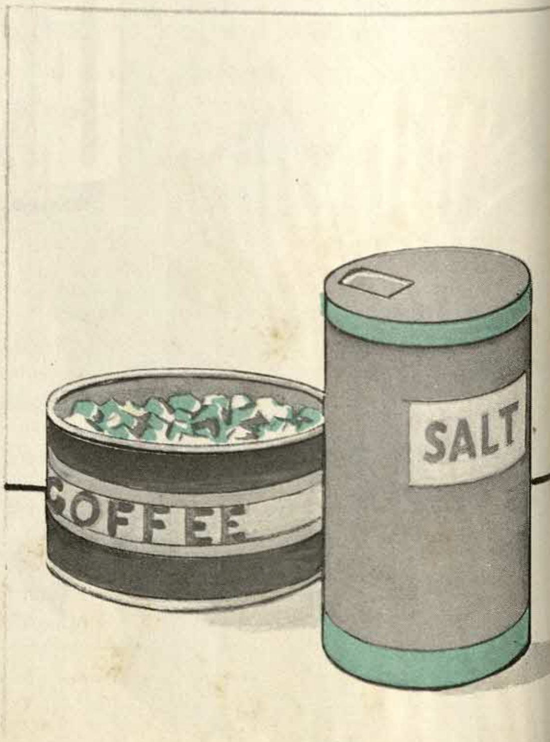
Would you expect the humidity in your home in winter to be high or low? Why? How can moisture be added to air indoors in winter? Why should there be some moisture in the air for comfort?

Why is it that if the temperature outside in the summer drops to 65° you are quite comfortable, but if the temperature in your home is 65° in winter you are cold?

Dew and Frost

ACTIVITY Fill a glass with water and let it stand in the room for 15 minutes. The water should now be at room temperature. Pour this water into a shiny can. Put a thermometer in the can and record the temperature. Add ice cubes to the water, stirring the water gently. Watch the outside of the can. As soon as droplets start to form on the can, record the temperature of the water. This temperature reading is the "dew point" for the temperature of the air in the room.

Sometimes in the early morning you may see tiny droplets of water on blades of grass or flowers. Where do these droplets come from? Why are they formed? Droplets of water formed in this way are called dew. The temperature at which dew is formed is called the dew point. Why does the dew point vary at different times? If temperature and dew point are close together, what



conclusion do you draw about the relative humidity?

DISCOVER Take a coffee can, crushed ice, and salt. Put the salt and crushed ice in the coffee can, and stir the mixture. If you scratch your fingernail over the surface of the can, you will discover something different from dew. Why is this form of condensation different? If you are not sure, test the temperature of the mixture with a thermometer. ☐☐

If the temperature of the air near the earth is below freezing and the air is cooled, water vapor condenses to tiny ice crystals, and is called frost. Explain the difference between frost and frozen dew.

Fog

Have you ever looked outside early in the morning and found that the air around your house appeared to be "cloudy"? On some mornings, perhaps you have even had difficulty seeing the house across the street. How do you describe this condition? The following activity will help you to understand what causes fog.

DESCRIBE Rinse a milk bottle well in very hot water. Pour about 3 inches of boiling water into the bottle. Cover the top of the bottle with an ice cube. What happens inside the bottle? ☐☐

If the earth is cooled rapidly during the night, what happens to the temperature of the air next to the earth? If a light wind is blowing, this cool air comes into contact with warmer air a short distance above it. What happens when this warmer air is cooled? The blanket of condensed water vapor that sometimes forms near the ground is called fog. What causes fog to disappear?

DISCOVER Boil water in a teakettle. The little cloud that appears is sometimes called "steam," but it is really condensed water vapor. Can you explain why the cloud of condensed water vapor disappears when you turn off the heat under the teakettle?

Formation of Clouds

ACTIVITY Rinse the inside of a clean milk bottle with hot water. Light a match, and then blow it out. Drop the smoking match into the bottle. Stand with your back to the light. Suck air out of the bottle. What happens? When you sucked air from the bottle, the air remaining in the bottle expanded. What change in temperature takes place as air expands?

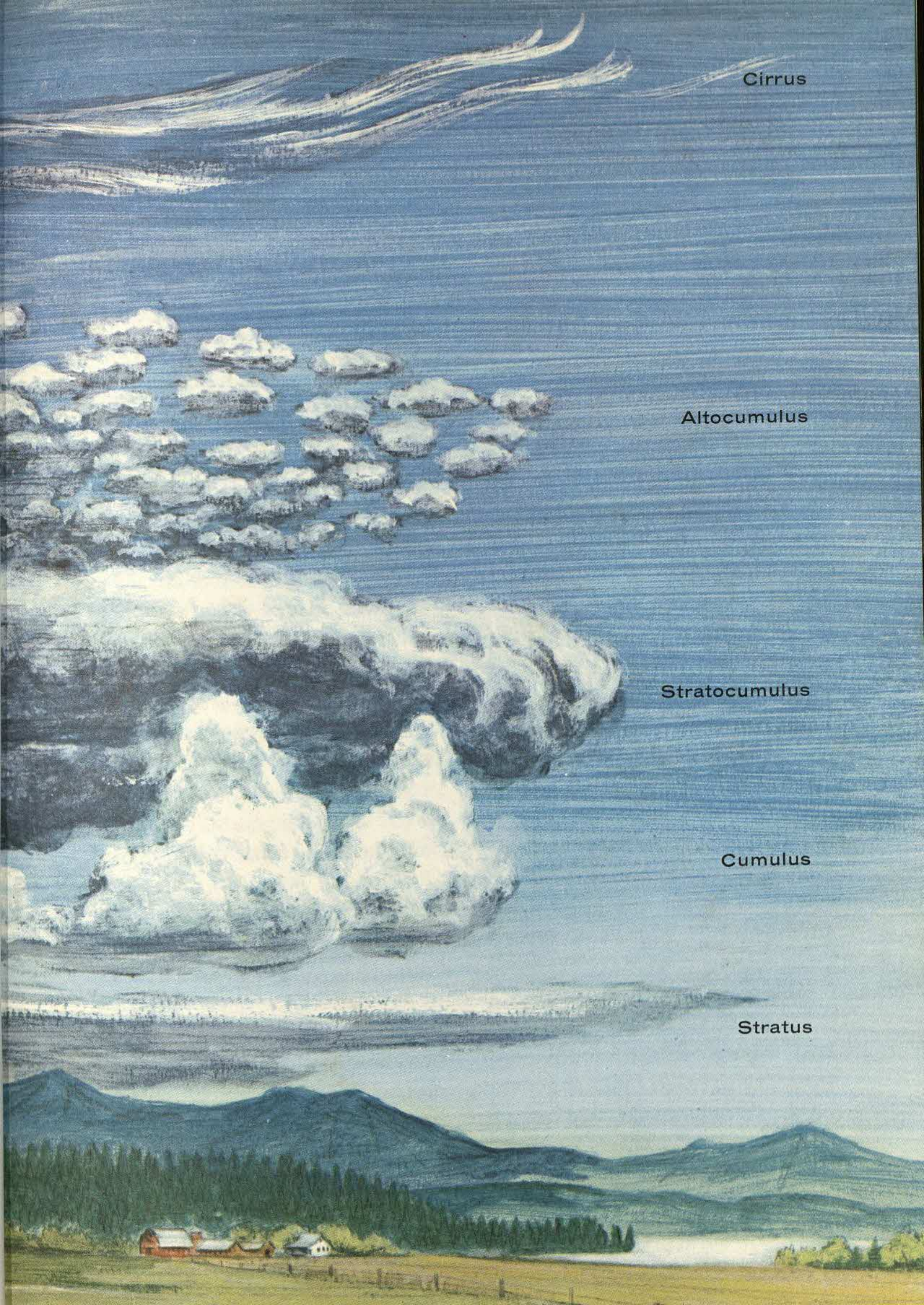
EXPLORE Take a large fruit juice can (No. 10). Put some ice mixed with salt in the can. Set a smaller can (No. 2) on the ice. The tops of both cans should be even. Pack more ice and salt into the space between the two cans. Breathe into the smaller can. What happens?

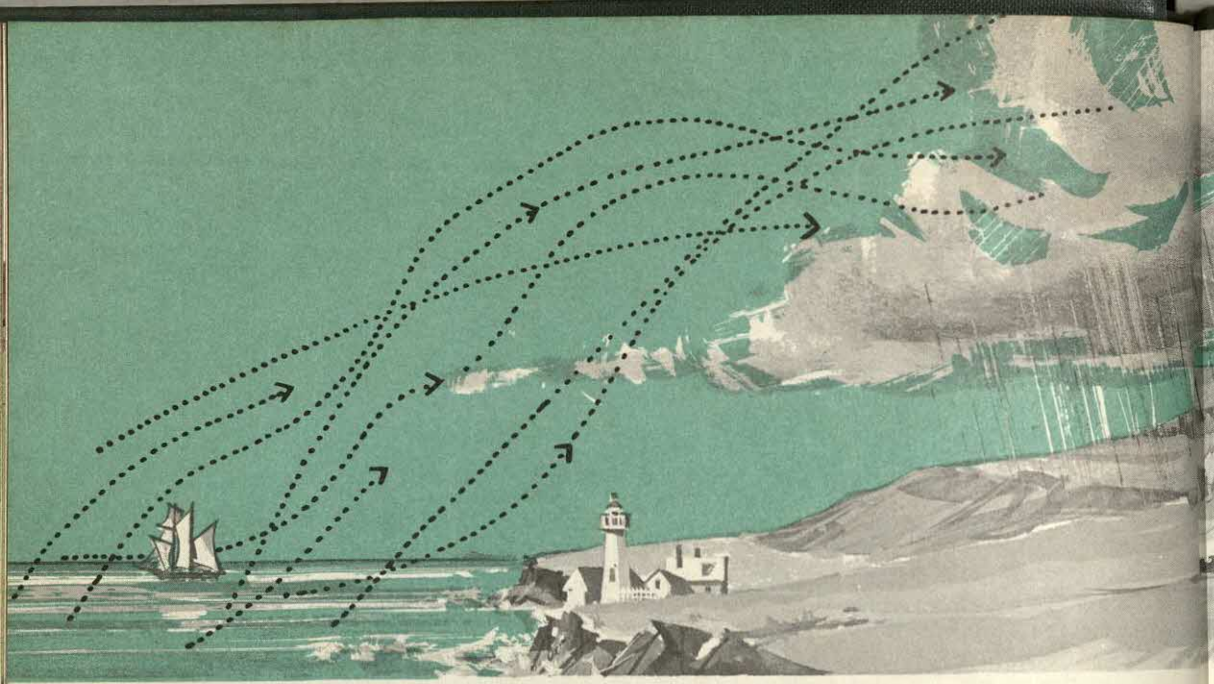
What happens to warm air as it rises in the atmosphere? If air is cooled enough, what happens to some of the water vapor in the air? What causes the cloud of condensed steam to appear over a kettle of boiling water? Explain why you can "see your breath" on a cold day. What causes fog? In each instance you see a mass of tiny droplets of condensed water vapor. When a mass of these droplets appears high in the sky, what is it called? What is the difference between clouds and fog?

Shine a flashlight or a movie projector through the air in a darkened room. What do you see in the beam of light? Particles of dust and other impurities are scattered throughout the atmosphere. When condensation takes place in the air, droplets of water form on these particles. Can you explain how the smoke from the match you dropped into the milk bottle helped to form a tiny cloud?

Types of Clouds

Observe the shapes of clouds that appear in the sky, and keep a record of the date and time you see the clouds and the kind of weather that accompanies and follows each cloud type. Make drawings of the various cloud


Cirrus
Altocumulus
Stratocumulus
Cumulus
Stratus



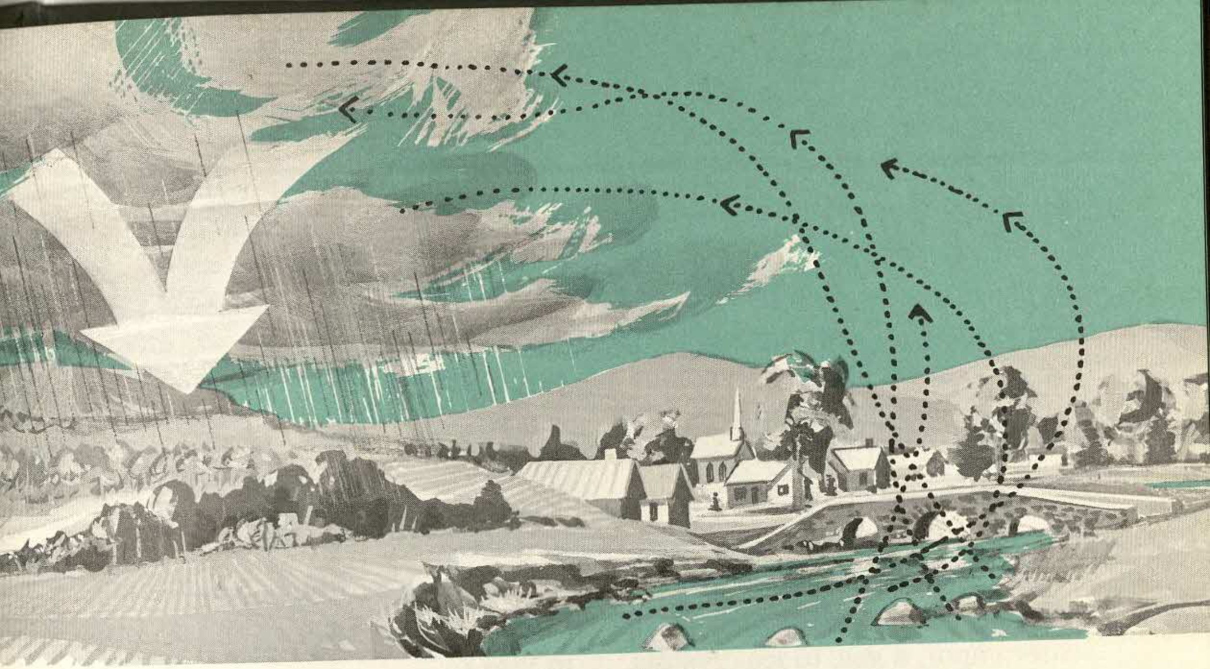
types you see. You can make models of cloud types by using pieces of cotton glued on cardboard.

In 1803, an English chemist named Luke Howard devised a system for naming the various cloud types. Large, fleecy clouds which form at moderate heights in the atmosphere are called cumulus (KYOOM-yoo-lus) clouds. What kind of weather usually accompanies this kind of cloud? Cumulus clouds can build up to thunderheads—always a sign of rain.

Thin, wispy clouds high in the atmosphere are called cirrus (SIH-rus) clouds. Cirrus clouds form from five to seven miles above the earth. What would you expect the condensed water vapor in these clouds to be? What kind of weather often follows this type of cloud?

Thin, flat, layer-like clouds in the lower part of the atmosphere are called stratus (STRAY-tuhs) clouds. What kind of weather may stratus clouds bring?

These three types of clouds—cumulus, cirrus, and stratus—are probably the ones you see most often. However, these types can combine to form other types. Other cloud types are named by adding to the names of the three basic types. "Alto" means high, "nimbo" means rain, and "fracto" means broken. What kind of weather accompanies cumulonimbus clouds? nimbostratus clouds? altocumulus clouds? What does a cumulonimbus cloud look like? Why are some clouds at higher altitudes than others?



The Water Cycle

Water is constantly evaporating from the surface of the earth. Would you expect the earth to dry up eventually? Why? You have learned how water is warmed, changes to water vapor, rises, expands, cools, condenses, and forms clouds. A water cycle takes place while our weather is being produced. What stage in this cycle follows the formation of clouds?

Precipitation

Clouds consist of water vapor that has changed back to water in the form of tiny droplets or miniature ice crystals. These droplets are very small. Most raindrops are about a million times larger than cloud droplets.

Recall what you know about the circulation of air in the atmosphere. What kinds of air currents cause clouds to remain suspended high above the earth? What happens when the upward currents of air are not strong enough to keep the particles suspended? Rain, mist, snow, hail, and sleet, all of which are forms of condensed water vapor, are called precipitation (preh-sip-ih-TAY-shun).

Often the condensed water vapor near the top of a cloud is in the form of ice crystals or snowflakes. Can you account for this condition? Snow always starts as ice crystals. Scientists do not know exactly how rain is formed. Some scientists think that rain usually starts as ice crystals. What do you think determines whether these crystals fall as rain or as snow? Many people think that snow is frozen rain. Is it?

DESCRIBE Obtain some dry ice. Be very careful when handling dry ice; do not touch it with your bare hands. Make a cloud as you did on page 46. Chip a few small pieces off a chunk of dry ice. Drop the bits of dry ice into the cloud. Then shine a flashlight into the small can. Breathe gently into the cloud several times at two-minute intervals. Describe what you see happening. ☐☐

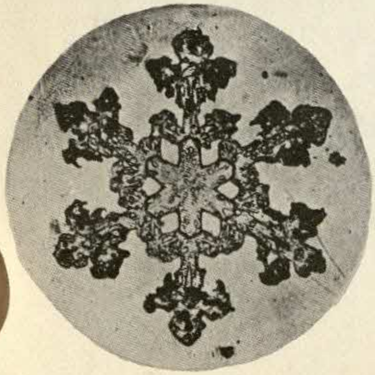
Snow is formed directly from water vapor, a gas, to ice crystals, a solid. There is no liquid state between these two.

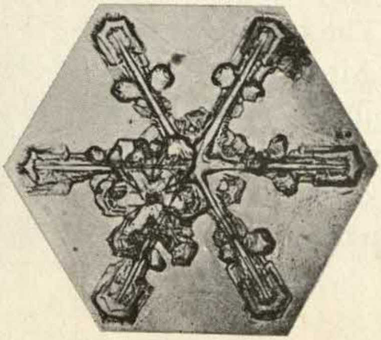
If you live in a climate where it snows, go outside when it is snowing, and catch some snowflakes on a piece of black cloth or paper. Examine each individual snowflake with a magnifying glass. Describe the appearance of the flakes. You will find that snowflakes are very beautiful and that there are no two alike.

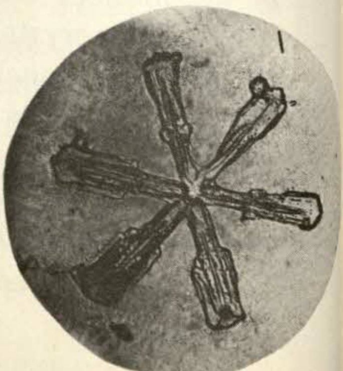
Each single snowflake has six points and six sides. It is possible that some of the flakes you examine were broken before they reached the earth. Some of the flakes you see may actually be tangles of crystals caught together.

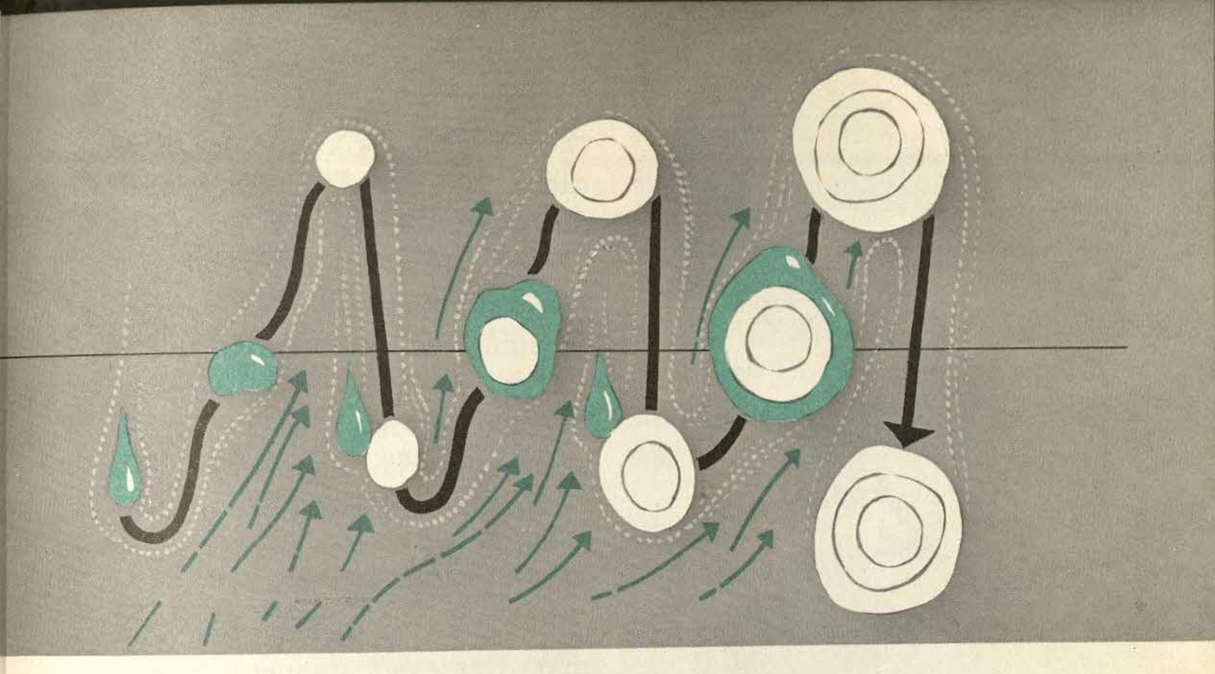
If raindrops freeze after falling from a cloud, what form of precipitation do we have? Sleet is often mixed with rain, and may form an icy coating on the ground. Sometimes rain freezes when it touches trees and other objects on the earth, forming glaze. What causes the freezing that results in glaze?

Have you ever noticed that during a snow storm, some snowflakes are carried up and down many times before they reach the ground? What causes this movement? Droplets move around in a cloud much as snowflakes move in the air. If droplets of water in a cloud were quickly pushed up to the top of the cloud, what would you expect to happen? These frozen particles may fall and be swept up again within the cloud several times. Each time the particle falls into the warmer section of the cloud it adds a coat-









ing of water. As the particle is swept up again into the colder part of the cloud, what happens to this coating of water? When the ice particles are so heavy that they can no longer be lifted by upward air currents, they fall to earth as hail. Hailstones are usually small and harmless, but at times they may grow to the size of baseballs before falling to the earth. Can you explain why some hailstones are larger than others? If you can find a hailstone, cut through a large one. You can see a number of layers, which look like the layers of an onion. Count the layers to find out how many times the hailstone started downward in a cloud and was caught up again. It is possible for a hailstone to consist of twenty or more layers of ice. Large hailstones can cause great damage to crops. Hailstorms usually occur in summer, often over the Great Plains section of our country.

"Man-made" Rain

Man can predict weather conditions and prepare himself for these conditions, but can he do anything to change the weather? If given the right conditions, meterologists may be able to "produce" rain.

OBSERVE Fill a very clean pan with distilled water. Cool the pan of water in the freezing compartment of the refrigerator. Keep a thermometer in the water, and check the temperature as the water cools. The water should be cooled below 32°F, but should not freeze. Water in this condi-

tion is called supercooled water. Drop a few thin wood shavings into the supercooled water. What happens? □□

You know that all clouds do not bring precipitation. Sometimes, even in clouds with temperatures below freezing, ice crystals do not form. Meteorologists can sometimes "make" rain by dropping pellets of dry ice or similar substances into cumulus clouds. This process, which is called "cloud-seeding," forces condensation to occur, and rain falls from the cloud. Such "artificial" rain has been produced to relieve drought-stricken areas and to extinguish forest fires.

Cloud-seeding must take place at exactly the right moment—when the temperature of the cloud is below freezing, and before ice crystals have formed. Since it is very difficult to determine this exact moment, cloud-seeding is successful only part of the time. Much study and experimentation must still take place before man can actually control even this one phase of the weather.

Measuring Rainfall

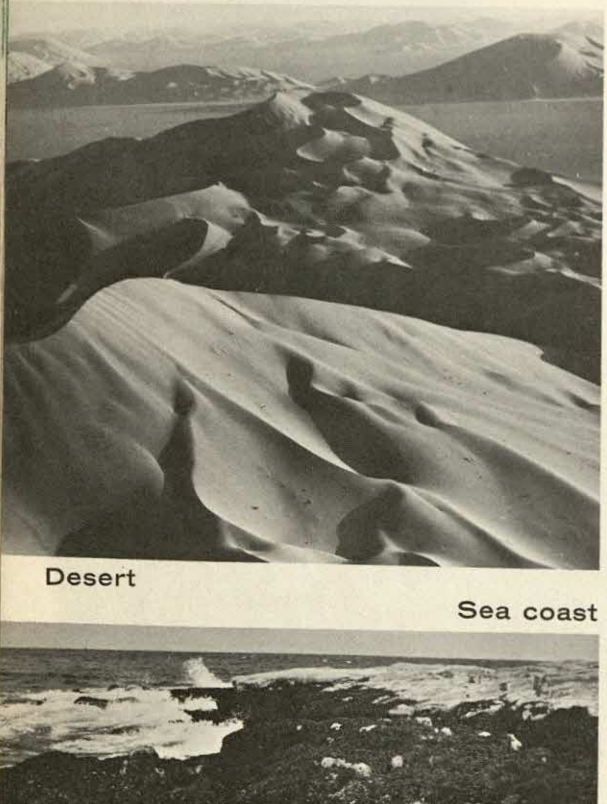
EXPLORE Glue a strip of paper to the outside of a tall olive jar. Take a large, flat-bottomed glass jar with straight sides, and pour one inch of water into it. Pour this water into the olive jar, and mark the paper at the top level of the inch of water. This height in the olive jar corresponds to an inch of water in the large jar. Divide the distance between the bottom of the olive jar and the mark on the paper into two equal sections. Mark the paper at this point. Divide each of these sections into two equal parts. You can now measure on the olive jar, heights which correspond to ¼, ½, ¾, and one inch in the big jar. Place the large jar outside in a level, open place. After a rainstorm, pour the water from the large jar into the olive jar. Use a funnel when pouring the water. If the water measures more than an inch, empty the olive jar, and then pour in the rest of the water; the height the water reaches plus one inch is the rainfall for that particular storm. □□

When you record rainfall, also write down whether the precipitation fell as a drizzle, a slow steady rain, a heavy pelting rain, or a downpour. From your record after each storm you can make four charts to keep a record of the rainfall in your part of the country. Your four charts should record the rainfall for a day, a week, a month, and a year. From the day chart compile the chart for each week, from the week chart the one for each month, and from the month chart, the year's record. Why might your rain gauge be inaccurate?

The first rain gauge was set up by King Louis XIV of France in 1684. He wanted to find out how much rainwater he could expect for use in the fountains at his palace in Versailles. His measurements were as exact as the ones the weathermen make today.

The average rainfall for the world during one year is about 32 inches. How could you find the average rainfall in your part of the country for a year? If all of

Rain Forest



Desert

Sea coast

this 32 inches of rain fell everywhere at once, the earth would be covered by almost three feet of water. Some places on the earth's surface receive practically none of this rain, while other places have as much as 400 inches of rain in one year. The wettest spot in the world is in India, where 100 inches of rain have fallen in four days and as much as 1,000 inches have fallen in a year.

Air Masses

Characteristics of Air Masses

A very large amount of air with fairly uniform temperature and humidity is called an air mass. From where does an air mass acquire its temperature and humidity? In each of the pictures, how do the surroundings affect the temperature and humidity of the air?

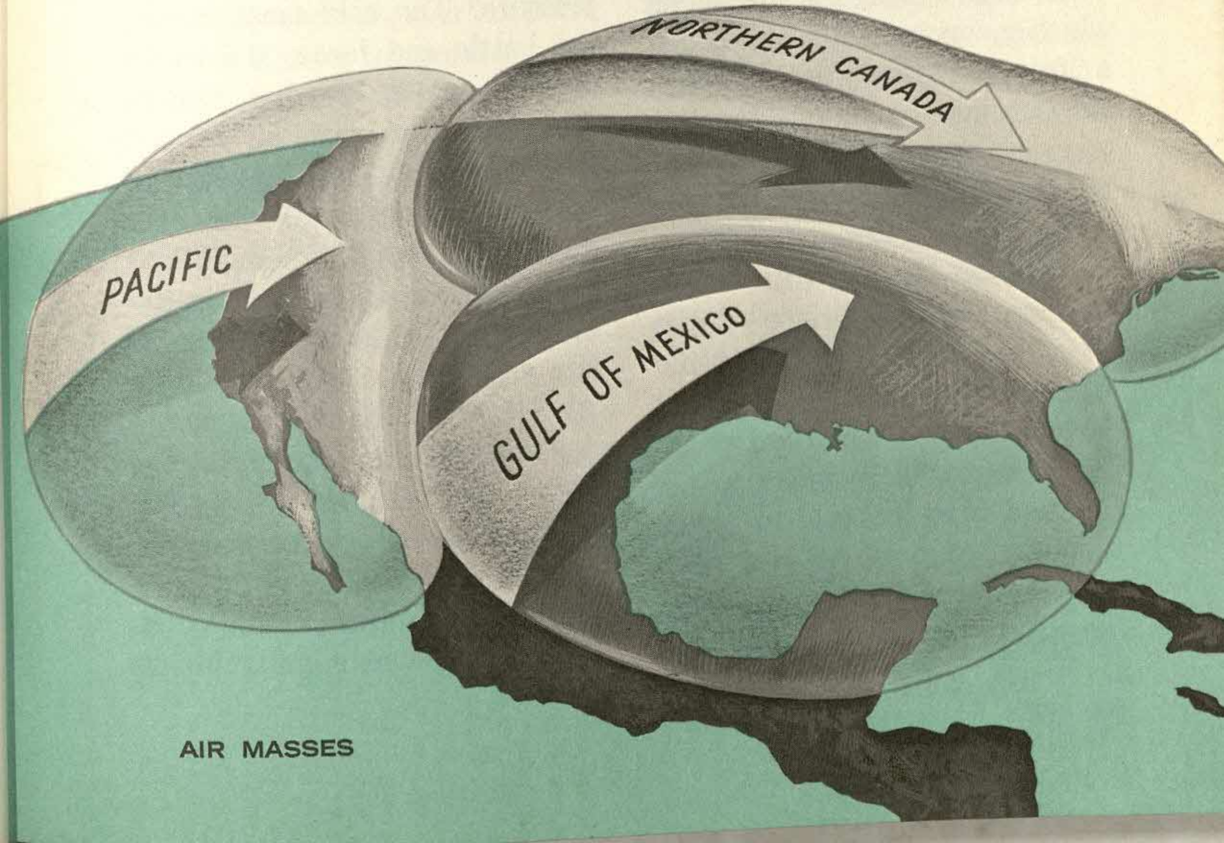
When you think of an air mass which affects our weather, you will have to think in terms of very large dimensions. An air mass may be miles high and may cover millions of square miles of the earth's surface.

When an air mass remains over an area for a long enough period of time, it acquires a certain temperature and humidity. What characteristics do you think are found in an air mass that forms over tropical seas? over Arctic seas? over cold, northern land areas? over tropical land areas?

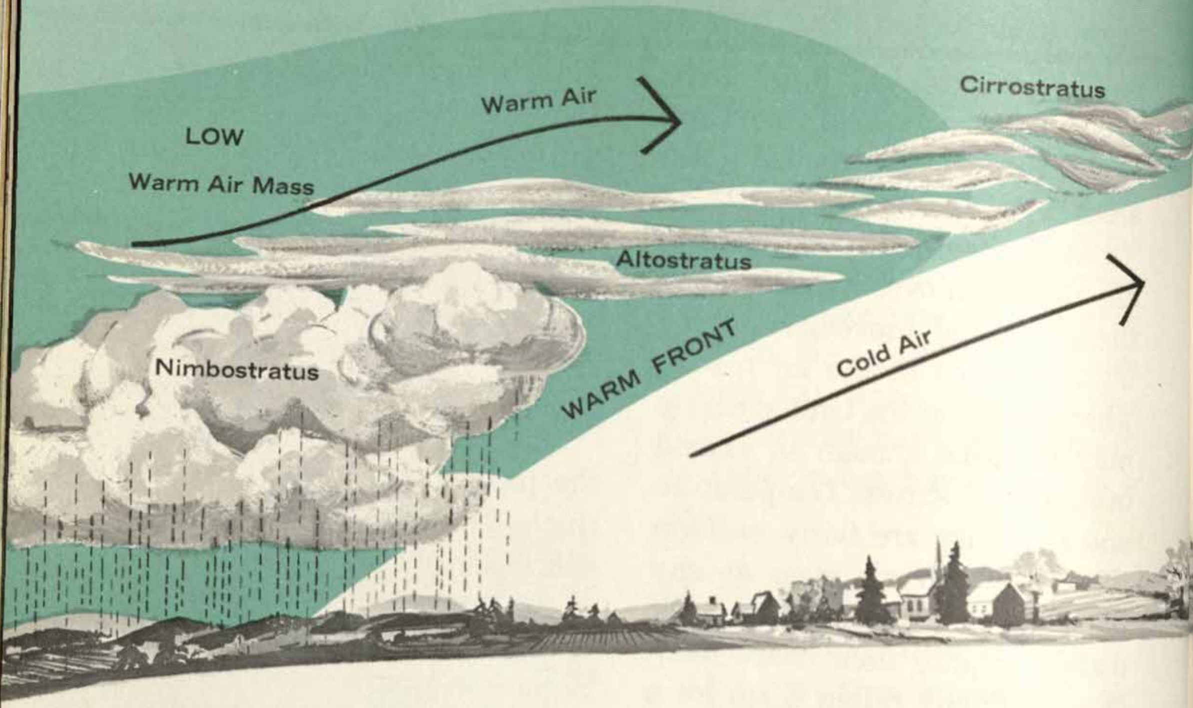
After they have been formed, air masses move. What causes the horizontal movement of air masses? Some of the air masses which pass over the United States may be large enough to extend over several states. Temperature and humidity are fairly uniform throughout an air mass at any particular altitude. After air masses acquire their characteristics, they may retain them for a distance of hundreds of miles as they move. Air masses are also affected by the areas over which they pass, and change gradually from day to day as they journey over land.

Do all air masses travel at the same speed? Sometimes they just drift along slowly, at speeds of less than ten miles per hour; at other times they may travel almost twenty-five miles an hour.

Explain how each air mass in the picture was named. Do you think there are other air masses which are not shown in this picture? How many air masses affect the weather of the United States? In what general direction across the United States do these air masses tend to move?



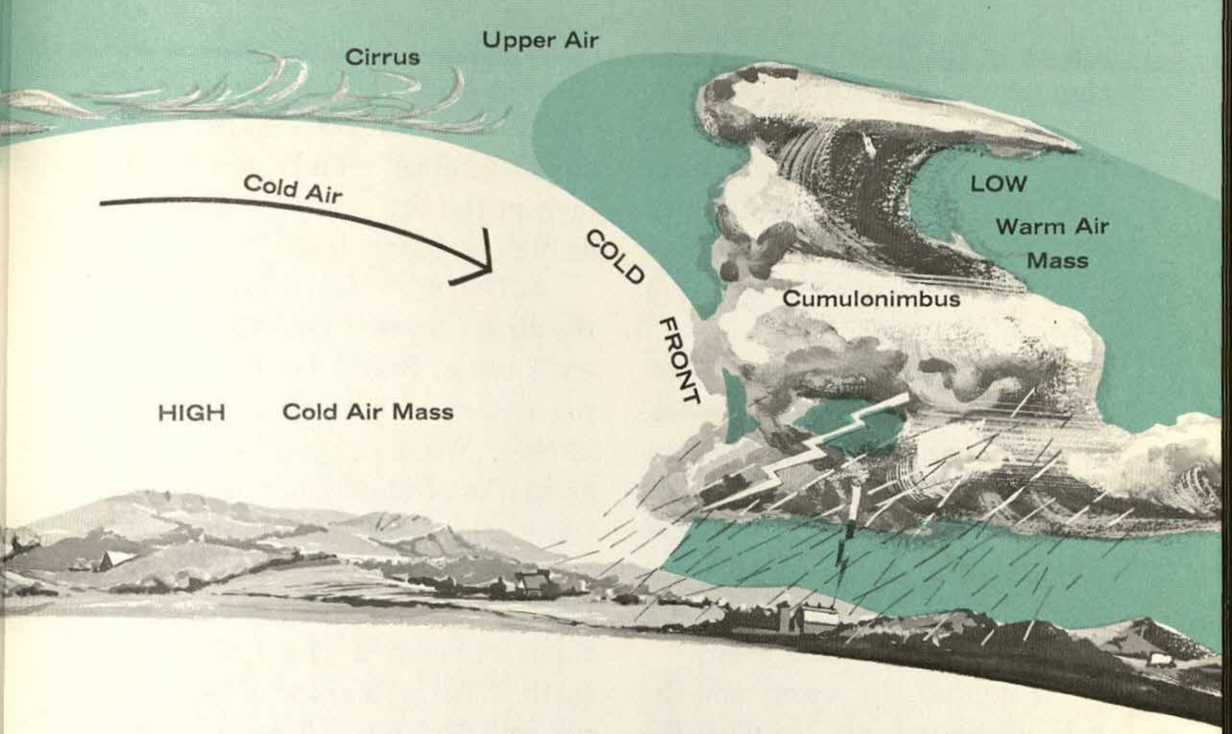
AIR MASSES



Fronts

During a war, the line along which enemy armies clash is called a "front." When two very different air masses collide, a "battle" takes place; the forward boundary of a moving air mass is also referred to as a "front."

Suppose that two masses of air close to the surface of the earth are moving in the same direction. One mass is cold and dry; the other is warm and moist. The cold mass follows the warm. Suppose that the cold air overtakes the warm air. Air in the two masses cannot occupy the same space; the masses do not mix easily. A "weather battle" takes place. Which mass exerts greater pressure? The cold mass "wins" the battle and forces the warm mass to move. In what general direction is the warm air driven? Remember that both masses are also continuously moving forward. What would you expect to happen to the water vapor in the warm air as it moves? Why do rain and snow often occur at a cold front? Distant cumulus clouds, high in the sky, signal the approach of a cold front. As a cold front nears, these cumulus clouds grow thicker, finally developing into cumulonimbus clouds. What kind of weather do cumulonimbus



clouds bring? What changes in the barometer take place as a cold front advances over an area? What changes in temperature and humidity usually follow the rain or snow?

The warm air mass that has been forced upward can move forward faster when it is high above the ground. Suppose that it moves fast enough to overtake another mass of cold air. Why does the warm air not push the cold air upward? The warm air partially encircles the mountain of cold air, and pushes the cold air forward.

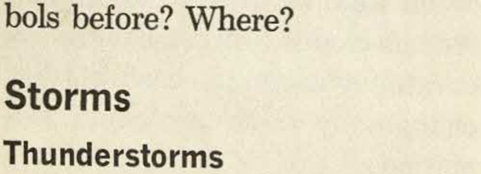
You can predict the approach of a warm front by observing cloud formations. High cirrus clouds are often the first sign of an approaching warm front. What do cirrus clouds look like? After a period of about 10 to 12 hours, these cirrus clouds are gradually replaced by lower and lower stratus clouds. Describe the appearance of stratus clouds. Finally, after another period of about 10 to 12 hours, low clouds of the nimbostratus type appear. What kind of weather do nimbostratus clouds bring? See how accurately you can forecast weather changes by observing cloud formations.

Why does precipitation develop along a warm front? How can a barometer help to predict an approaching warm front? What changes in temperature and atmospheric pressure take place after a warm front has passed over an area? What name is given to the atmospheric condition which accompanies the arrival of a warm air mass?

Sometimes a warm air mass is lifted between two cold masses, and a "closed in" front occurs. This front is called an occluded (ok-KLOO-duhd) front. Weather conditions at an occluded front may be similar to those at either a warm front or a cold front.

If neither the warm nor the cold air mass is able to push the other, a stationary front occurs. At a stationary front, weather conditions are similar to those at a warm front.

Meteorologists use the following symbols to identify fronts:



Have you ever seen these symbols before? Where?

Storms

Thunderstorms

Describe the kind of clouds you see in the sky shortly before a thunderstorm. These clouds are called cumulonimbus clouds or thunderheads. What does "nimbus" mean? Can you explain why cumulonimbus clouds tower so high in the sky, sometimes rising as high as 60,000 feet?

ACTIVITY On a day when the air is *very* dry, go into a darkened room. Stand before a mirror, and comb your hair in quick strokes. What do you see? Just as sparks of electricity move between the comb and your hair, so does electricity move between clouds, within clouds, and sometimes between a cloud and the earth. What is this kind of electricity called? You will learn more about lightning when you study electricity. □□

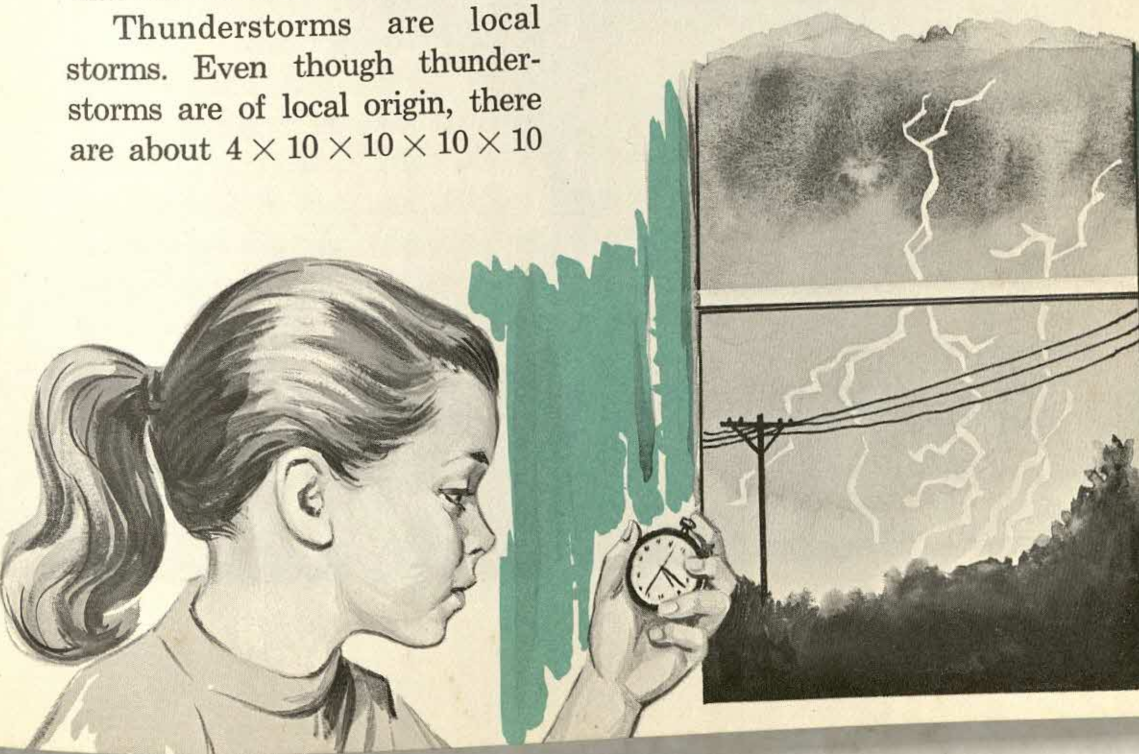
You know that thunder always accompanies lightning. What causes thunder? As an electric spark moves through the air in a cloud or in the atmosphere, the air is heated very rapidly, and expands suddenly with a burst of noise. Thunder and lightning happen at exactly the same time. Why do we hear thunder after we see the lightning that caused it? In one second, sound would travel back and forth in your classroom about fifteen times. Light would travel around the entire world seven times in the same second. If you watch a carpenter hammering nails or a man chopping wood at a considerable distance from you, which do you notice first, the action or the sound of the action?

ESTIMATE You can determine approximately how far away from you lightning takes place. Use a watch with a second hand, or count the number of seconds between the time you see the lightning and the time you hear the thunder. Divide the number of seconds by 5 to determine approximately how many miles away the lightning flashed. Lightning flashes in an instant, but thunder rumbles on for a longer time. Why? Lightning may be dangerous, but thunder is never dangerous. Once you hear thunder, you know the lightning flash that caused it is over. □□

Thunderstorms are local storms. Even though thunderstorms are of local origin, there are about $4 \times 10 \times 10 \times 10 \times 10$ of them every day throughout the world.

You may have heard someone say, "The thunderstorm is coming back." This is impossible. Once a thunderstorm is over, it has spent itself. The new storm is just that—another storm coming and going the same way the first one did.

An important factor in the production of thunderstorms is a great difference between warm air near the ground and cold air high above the ground. Because these differences in temperature are so great, there are quick upward and downward movements of air. This difference occurs either because the ground has suddenly become greatly heated or because the air above has been suddenly cooled.



Tornadoes

Have you ever noticed dried leaves and bits of paper whirling about in the corner of your schoolyard? Have you seen snow whipped into spirals by the wind?

This spiral twisting of the wind causes storms called "dust devils" to form in desert regions. A spiral-shaped storm that is like a dust devil magnified hundreds of times is called a tornado. Just how a tornado originates is not known. This much is known—extremely hot air must come into contact with a mass of cold air before the whirling funnel of air is produced. At first a tornado looks very much like a thunderstorm. Then suddenly a dark funnel shoots out from the base of a thundercloud and extends toward the earth. Within the funnel, winds whirl at speeds so high that

meteorologists have not been able to determine their force.

Air in the funnel is constantly forced outward, leaving in the center a low pressure area which is almost a vacuum. As a tornado passes over the ground it acts like a giant vacuum cleaner, picking up objects in its path.

Accounts given by people who have experienced tornadoes show how terrifying this storm can be. Tornadoes lift houses, railroad cars, and huge trees, usually destroying the objects they pick up, but sometimes setting them down unharmed at some distant place; men and animals have been carried great distances without injury. Winds in a tornado are strong enough to drive a straw into a wooden pole and shoot sand grains with the speed of bullets.

If the funnel passes over a large building, the building often explodes. Recall what you know about air pressure. What causes the building to explode? If a tornado is predicted, would it be better to open the windows of a house or to close them? Explain your answer.

Most tornadoes in the United States take place in the central part of the country. The reason they seem to be concentrated in this particular area is that here two air currents, entirely different in temperature and humidity, often meet; one is moist and warm, the other cold and dry. Tornadoes at sea are called waterspouts.

The width of a tornado may vary from several hundred feet to about a mile. Some tornadoes are only as wide as a street, but these are among the most destructive.

Hurricanes

There are other whirling storms which are like tornadoes, but cover a much larger area and have a much longer course. These storms always originate over the ocean. They are called hurricanes. Because of their greater size, hurricanes are more destructive than tornadoes. Hurricanes are the most destructive of all storms.

The U. S. Weather Bureau keeps continuous watch in areas where hurricanes originate. Since all hurricanes originate above the ocean, it is possible to detect a hurricane before the storm reaches coastal areas. Meteorologists risk their lives, flying weather planes into hurricanes, in order to determine their strength and probable course. There are so many hurricanes each year that the Weather Bureau gives them girls' names,

Photograph of the eye of a hurricane.

first using a name that begins with A, then B, then C, and so on. How many hurricanes preceded "Diane" in 1955?

Hurricanes are probably started because of prolonged heating of the ocean near the equator. A spiral updraft is formed, creating heavy rains and swirling winds. Meteorologists still have much to learn about the origin of hurricanes.

In the center of a hurricane is a calm area where there is no wind or rain. Recall what you know about conditions at the center of a tornado. Is the atmospheric pressure at the center of a hurricane high or low? This area is called the "eye" of the hurricane. The eye may be as wide as twenty miles. Would you feel safe if you were in the eye of a hurricane? Explain.

Much of the damage caused by hurricanes is a result of the torrent of rain and the extremely high tides which accompany this storm. Huge tidal waves, which may rise to the height of 30 feet, dash against the shore, rocketing into the air. At the center of a hurricane, the ocean surface rises to abnormal heights, contributing to the formation of the high tidal waves. Can you suggest one reason why this rise in the ocean's surface occurs?

Both the U. S. Navy and the Weather Bureau have experimented with cloud-seeding as a way of forcing a hurricane to reach its climax over ocean areas and play itself out before reaching the coast. These experiments have been partially successful.

The southeast coast of the United States is the section of our country most likely to be struck by hurricanes. Here the greatest number of hurricanes occur during the months of August, September, and October. In the eastern hemisphere, hurricanes are called typhoons.

Blizzards

Heavy snowstorms are sometimes accompanied by strong winds and intense cold. Such storms are called blizzards. Sometimes, even when there is no precipitation, winds swirl masses of dry powdery snow to heights of several hundred feet, making visibility impossible. These severe winter storms occur primarily in central North America and in Russia. Blizzards disrupt necessary activity – transportation stops, industry shuts down, and deliveries of food and fuel are impossible.

Storms Are Necessary

Storms are of tremendous importance because they provide the precipitation necessary for life on earth. Even violent storms which cause destruction and loss of life can be considered as a way of restoring balance and equilibrium in the atmosphere. You might find it a little easier to accept the cancellation of a picnic or baseball game if you think of the benefits we get from a thunderstorm.

Climate

You have kept records of temperature, wind direction and speed, air pressure, humidity, and precipitation. Compile your data on daily and monthly record charts.

DAILY TOTAL RECORD

*DATE*________________

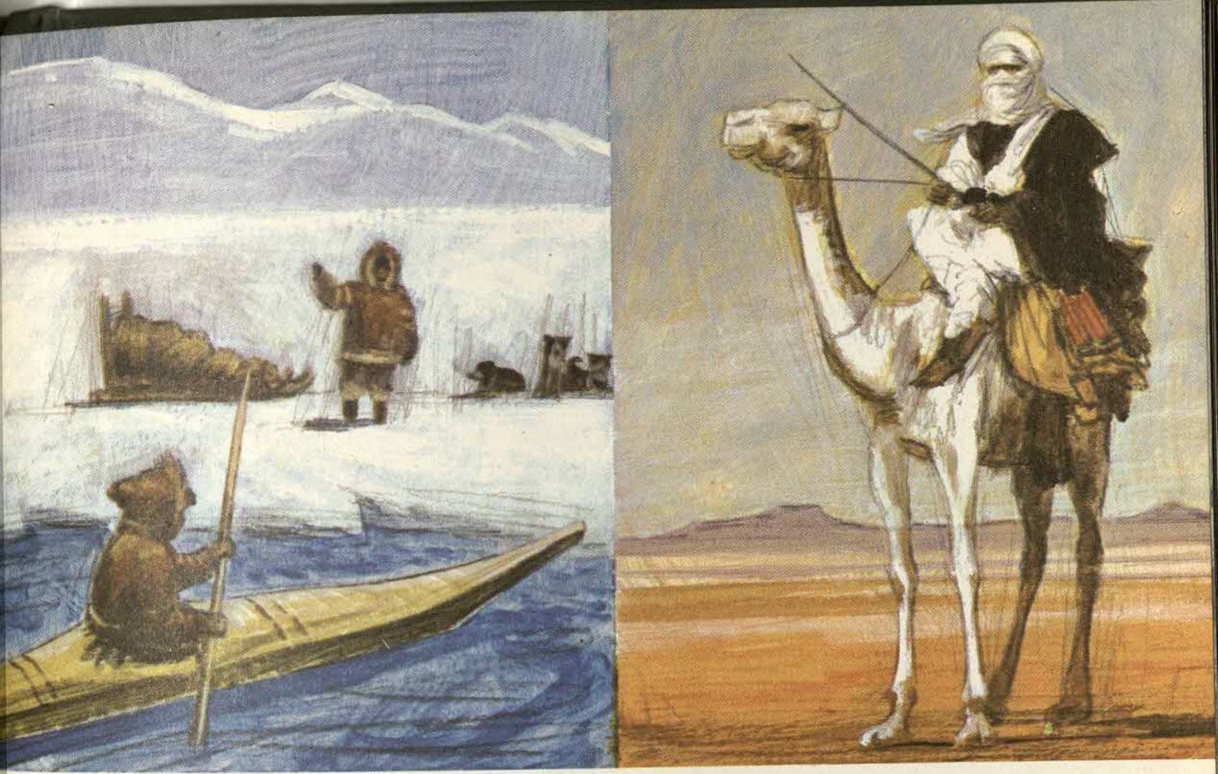
	A.M.	*P.M.*
Temperature		
Air Pressure		
Wind Direction		
Wind Speed		
Humidity		
Kind of Clouds		
Inches of Rain		
Other Precipitation		

MONTHLY RECORD

*MONTH*________________

Average temperature

	How many times "high"
Humidity________________	How many times "low"
Rain	Number of days it rained
Snow	Number of days it snowed
Sun	Number of sunny days
Cloudy days	Number
Windy days	Number



Over a period of several months, what do these records tell you? What patterns can you see? The weather that affects one part of the world over a series of years is referred to as the "climate" of that particular region.

Write or call the Weather Bureau station nearest your community and find out the answers to the following questions:

Which month is the warmest?

Which month is the coldest?

What is the average temperature of the warmest month?

What is the average temperature of the coldest month?

What is the annual range of temperature?

What is the highest temperature recorded during the year?

What is the lowest temperature recorded during the year?

What is the average annual rainfall?

Which season has the most rain?

Which month has the most rain?

Which month has the least rain?

Consult an almanac or a Department of Agriculture Yearbook, and compare the climate in your community with climates in other parts of the country.

Why do regions near the equator have warm climates? Why do regions near the poles have cold climates? Think of some ways in which mountains, large bodies of water, altitude, and planetary winds can influence climate.

Climates vary to a great extent within the United States. However, the most common weather pattern in the United States occurs over and over—a few days of clear weather, then a few days of cloudy weather. In what direction do air masses move over the United States? Cold fronts advance at a speed of about 20 miles per hour. Warm fronts move at a speed of about 15 miles per hour, or less. Approximately how long would it take for a cold front to travel 100 miles? How long might it take for a warm front to cover the same distance? Explain how the movement of air masses across the United States results in a fairly regular weather pattern.

What effect does climate have on the kinds of homes we live in? the foods we eat? ways of earning a living? the time of day during which we work? products sold in stores? types of recreation we enjoy? Have you ever spoken with someone who lives in a climate different from yours? If so, what did you learn about ways in which climate influences people's lives?

The Daily Weather Map

If there is a Weather Bureau Station in your community, perhaps someone could arrange a visit for your class to the Weather Bureau. If you do make such a visit, you will be seeing one of more than 600 such stations located throughout the United States; the first dates back to 1890. In addition to these stations, there are also nearly 8,000 part-time stations. On special instruments, more accurate than yours, meteorologists make the same observations you have made. These observations are sent to a central Weather Bureau in Washington, D. C., in the form of coded numbers. Why do you think coded numbers are used? In Washington, trained men assemble the data on a large map. The result is a picture of weather conditions known as the daily weather map. The daily weather map is revised every six hours.

On the weather map, locate the symbols that look like musical notes. The circle represents a weather station, and the staff points in the direction *from* which the wind is blowing. The lines on the staff indicate the force of the wind. Look at the key at the bottom of the map to find out the meaning of these lines.

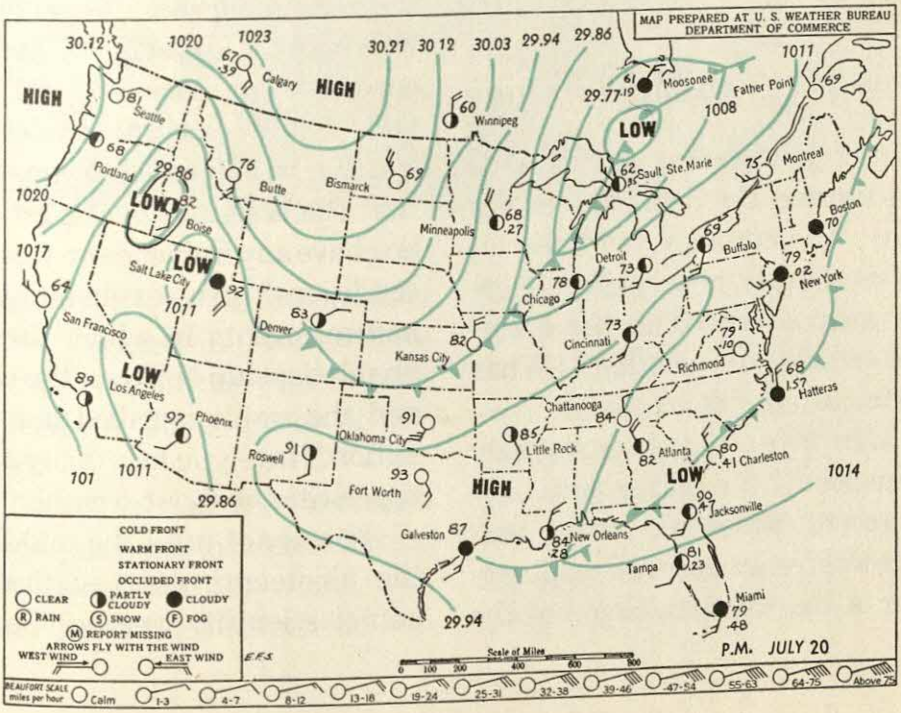
Some of the circles are black, some are partially black, and some are white. Read the code below the map. What do the different shadings mean?

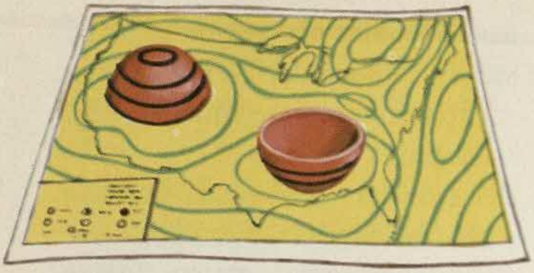
The number beside each circle tells the temperature. Below some of the temperature numbers is a number in decimals which tells the number of inches of precipitation that has fallen in the preceding six hours.

The lines on the map connect locations with the same air pressure, and are marked in millibars, units used to measure air pressure. Millibars are marked at the edges of the map.

Use the weather map shown here to answer the following questions:

1. What kind of weather is listed for Cincinnati? What is the direction of the wind in Cincinnati?
2. Give the speed and direction of the wind at Winnipeg.
3. Through what states does a pressure of 30.03 inches exist?
4. Name an area where the weather is cloudy, and the winds are southeast and moving between 8-12 miles per hour.
5. What kind of front is passing from Denver through Kansas City, Chicago, Sault Ste. Marie?
6. Name three parts of the country in which a low pressure area is found.
7. Describe the weather around New Orleans.





EXPLAIN Cut a rubber ball in half, and paint rings around the outside of each cup. Place one cup upside down on a weather map at a place where a high is indicated. Place the other cup right side up at a place where a low is indicated. The cups represent highs and lows. Since depth cannot be shown on a flat surface, the loops on a weather map may be misleading. Explain why the circles on the cups represent highs and lows better than the lines on the map do.

From Myth to Meteorology

At the beginning of this unit, you learned the definition of the word "meteorology." Meteorology is a fairly new science. How has man advanced in the scientific study of weather? What advances are yet to come?

Men have always been strongly influenced by weather, but only in recent times has man been able to give an accurate explanation of the weather. Some of the ancient Greeks explained winds by giving them personalities and telling stories, or myths, about them. According to one myth, the north wind, extremely rude and stormy, fell in love with a gentle nymph, but found it impossible to breathe softly and sigh, as a lover should. The calm, mild west wind, on the other hand, was more successful in wooing the goddess of flowers.

Can you suggest possible reasons why such a story might have developed? Does the story have *any* basis in fact? Myths may have originated as attempts to explain complicated happenings which man could not understand in a scientific way.

Some people believe that if the groundhog sees its shadow on February 2, it will be frightened into retreating to its den, and six weeks of unpleasant weather will follow. Do you think that the activities of the groundhog have any influence on weather conditions? An explanation of natural events in which there is no relationship between the cause and the result is called a superstition. Have you heard any other superstitions about weather?

It was not until the middle of the nineteenth century that an actual scientific weather bureau

was set up. From this first weather bureau, located in France, local weather conditions were telegraphed to other parts of the world.

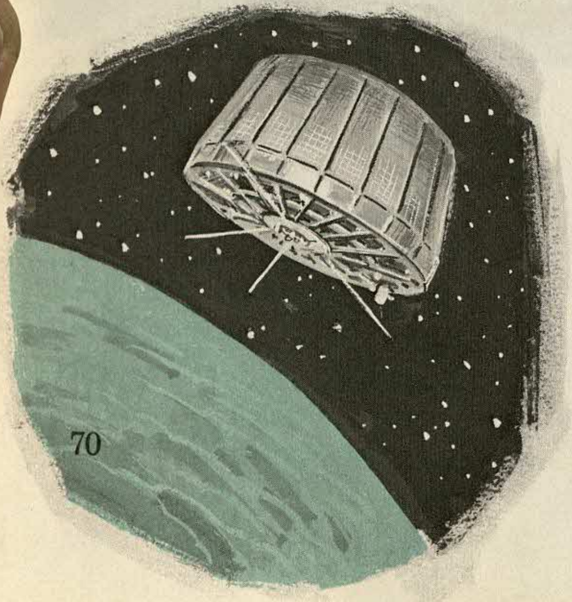
Today, about ten thousand weather stations, located in almost every country of the world, teletype observations to central stations, where weather information is compiled and interpreted.

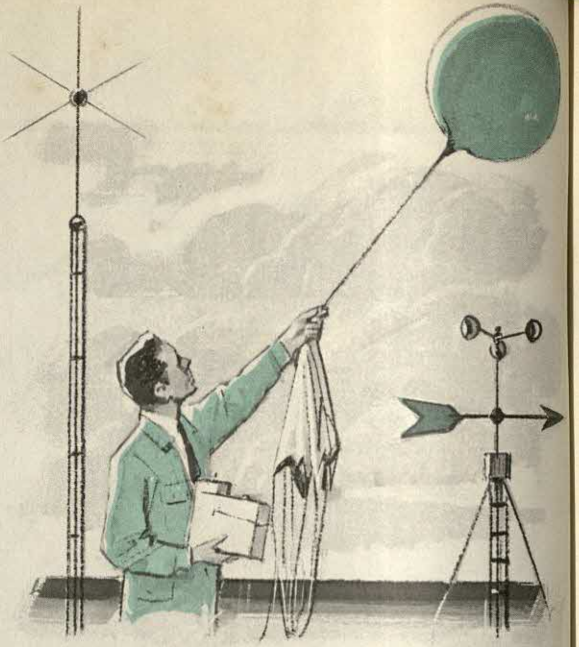
In addition to these permanent weather stations, there are unmanned stations in polar regions and seas, where it is difficult for men to live. Such stations transmit information automatically to manned stations.

Gas-filled balloons send back to earth information about temperature, humidity, and air pressure in upper regions of the atmosphere. These instruments, which send messages by means of ultra short-wave transmitters, are called radiosondes.

Radar is used to detect rainclouds, tornadoes, hurricanes, and other dangerous storms. Electronic computers aid in analyzing information quickly.

In 1960, the United States launched its first weather satellite, Tiros I, equipped with a television camera which could send pictures of cloud formations back to earth. The word "Tiros" comes from the name of the weather-satellite project—Television Infra-Red Observation Satellite. Tiros 8, launched in 1963, was equipped with an automatic picture transmission (A.P.T.), which can send instant pictures to receiving stations on the earth far faster than any previous satellite. Why is speed such an important factor in weather forecasting?





The next time you watch a weather report on television, think of all the work that has been accomplished in order to keep you informed about the weather. Much more progress remains to be made in our knowledge of the weather and in our ability to forecast weather.

Some people complain when a weather forecast turns out to be incorrect. Actually, the forecasts issued by the weather bureau are correct between 85% and 95% of the time. Recall all of the changes that can take place in the air; do you think the weatherman does a good job?

REVIEW Find relationships among the words in the list. Review the meaning of each word. Find other ways in which the words can be used to help you understand weather and climate.

- air mass
- aneroid barometer
- atmosphere
- atmospheric pressure
- cirrus clouds
- climate
- cold front
- condensation
- cumulus clouds
- dew point
- evaporation
- fog
- highs
- humidity
- hurricane
- hygrometer
- lows
- mercury barometer
- planetary winds
- snow
- thermometer
- thunderstorm
- tornado
- updraft
- warm front
- water cycle
- weather map
- weather station
- wind

FORECAST Using daily weather maps and your weather station, make your own weather forecast. See how close your forecasts come to the weatherman's and to the weather itself. □□

Would you like to take a trip in a balloon? Close your eyes and imagine yourself taking a trip of this kind. What might you see on such a flight? Do you think you might go so high that the earth appears round as you look at it far below?

A free-floating balloon flight would give you many exciting moments. Do you think your voyage would be dangerous? One balloonist was able to stay in the atmosphere long enough to drift some 2,000 miles. How do you think you might solve the problems of lack of oxygen, extreme temperature, and extreme pressure? In making preparations for your trip, what would you take with you?

How would a knowledge of heat, air, water, and weather help you during your flight? How would a knowledge of wind direction and speed help you? How could you gather scientific information about conditions of the atmosphere?

Pretend that you have been asked by the United States Air Force to write a weather report for a balloon flight. The flight is to take place just one week from today. Write the report. Be prepared to present your report to the class.

We Explore the Air Around Us

Air, Water, Heat, and Weather

If you travel in a balloon, the weather affects you. The weather affects you inside or outside your home, and it affects you at work or play. The weather depends upon air, water, and heat. These three things work together to make all the kinds of weather we know. In order to understand weather better, it is necessary to take a closer look at air and water and to discover more about them both.

Does Air Occupy Space?

DESCRIBE Reach out. What do you feel around you? Why can't you feel the air? Inhale. What happens to your chest as you inhale? Why? Does air occupy space?

ACTIVITY Take a drinking glass. Wash it out carefully in hot, soapy water, and rinse it in warm, clear water. Dry the glass with a clean towel. Hold the "empty" glass up and look through it. What do you see in the glass? Feel inside the glass. Is there anything in the glass, or is the glass empty?

ACTIVITY Fill a large, clean bowl or pan with water. Fill the glass with water from the bowl. Now hold the glass up and look through it. What do you see in the glass? Feel inside the glass. What do you feel? Can you smell anything inside the glass? Make a list of the differences between air and water that you have learned from these activities.

EXPLAIN Empty the glass of water and dry it. Take a cork, ping-pong ball, or some other object that floats, and drop the object into the water in the bowl. Invert the glass over the floating object. What is the level of the water under the glass? Why? Push the glass deeper into the water. What is the level of the water under the glass now? Why? What do you think will happen if you remove the air from the glass? Try it. What happens? Blow air back into the glass. What happens? Why?

DISCOVER Take a clean, empty, narrow-necked bottle that has a screw cover. Make a hole in the cover big enough to hold the stem of a funnel. Insert the stem through the cover. Seal the edge of the cover and the hole around the stem of the funnel with modeling clay. Pour water into the funnel. What happens? Why? How could you get the water to flow freely into the bottle? Try using other liquids, such as milk, vinegar, or juice. What happens? Why? Be sure you make the hole air-tight each time. □□

What do you hear when you open a vacuum-packed can? What is it that exists within a thimble, fills an "empty" bottle, hides in your closet, whistles through the trees, lifts a toy balloon, lurks between cracks, fills your lungs, and makes clothes on a line flutter and flap? What is it that you always find, no matter where on earth you go, whether it is down into a subway, through a tunnel, into a house, or outdoors for a walk? In what layer of this ocean of air do you live? What have you learned about air?

EXPLORE Try this activity for further evidence of what air is. Put a two-hole stopper into the top of a narrow-necked bottle. In one hole insert the funnel, and in the other a bent glass or plastic tube. Use modeling clay to make the top air-tight. Over the end of the glass tube, tie a toy balloon. Pour water into the funnel. What happens to the water this time? What happens to the balloon?

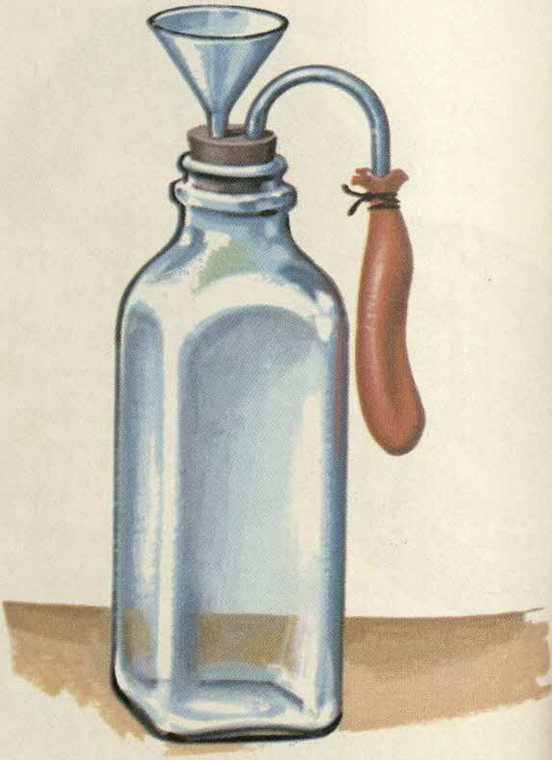
Continue pouring water into the funnel until the bottle is filled. What has happened to the balloon? Why? Pour some water out of the bottle. What happens to the size of the balloon? Why? What happened to the air in the bottle as the water was poured into it? Remove the balloon, and hold your finger over the end of the glass tube. Fill the funnel with water. Open and close the tube. What happens? Why do you make two holes in the top of a can before you pour out a liquid? □□

Air occupies space. Water occupies space. Can two material substances occupy the same space at the same time?

Air Can "Move" Water

As early as 100 B.C., a device that could lift water from a well had been invented. This device was called a lift pump.

In the lift pump, there is a section that can be moved up and down by the handle. The part

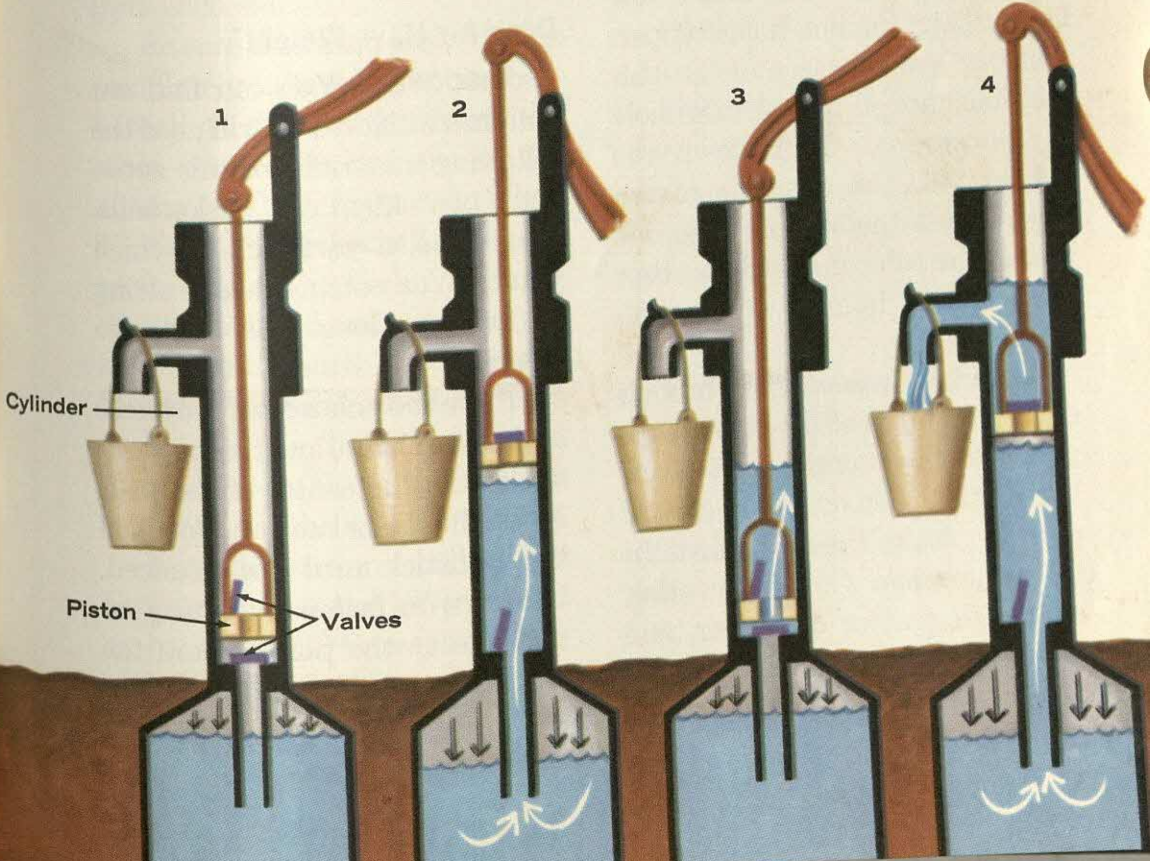


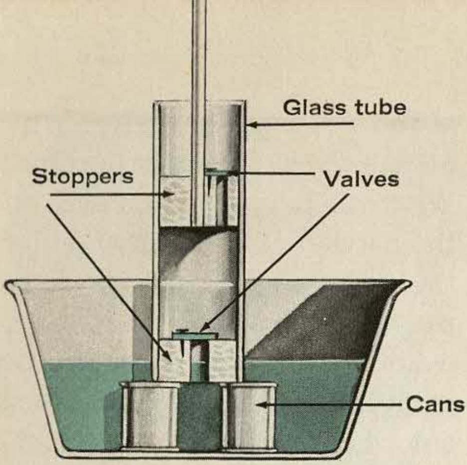
that moves is called the piston. The rod that connects the piston to the handle is the piston rod. The section in which the piston moves is called the cylinder. The terms "piston" and "cylinder" are used to name the movable and unmovable parts of many machines.

Look at the picture of the lift pump. In the piston and at the bottom of the cylinder, there are openings which have small covers that move only in an upward direction. These covers are the valves. Locate the piston valve and the cylinder valve.

How does this device lift water? What occupies the space in the cylinder and in the section of the well over the water? Why doesn't the water rise in the pipe? What will happen as you push on the handle? What is lifted out of the cylinder? The first people to use lift pumps believed that the water was pulled up into the empty space as the air was lifted out. Looking at the diagram, would you say they were correct?

Why did Torricelli become interested in the lift pump? What did Torricelli believe forced the water to rise in the cylinder? Look at the pictures to see what happens in the cylinder of the lift pump as the piston moves up and down. What will happen on the next stroke?





ACTIVITY You can make a lift pump if you can obtain a glass tube about six inches long, and two stoppers that fit the tube. One stopper must have one hole. The other must have two holes, and must be small enough to fit entirely inside the tube. You will also need a balloon, a round stick longer than the tube, and a few tacks. Take the one-hole stopper. Cut out a small piece of the balloon big enough to cover the hole in the stopper. Tack down the rubber piece on one side of the hole. Insert the stopper into one end of the tube, making sure that the covered hole is on the inside.

Insert the round stick through one of the holes of the other stopper. Wet the stopper, and screw in the stick. Use modeling clay or putty to make the stick air-tight in the stopper. Cover the other hole with a piece of rubber, and tack it into place.

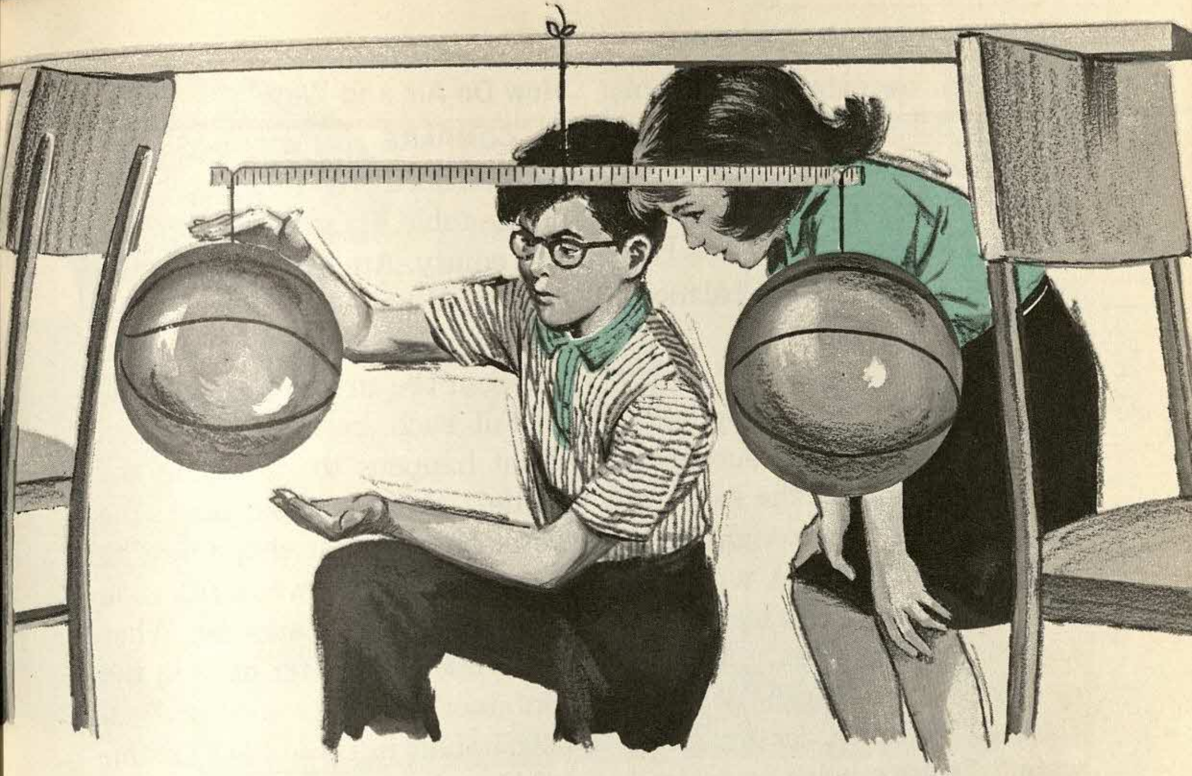
Wet the stopper, and place it inside the glass tube. Take a pan, and partly fill it with water. Put two flat cans in the bottom of the pan so you can rest your pump on them. Work the piston up and down. Observe what happens and explain. □□

Torricelli knew how lift pumps work in wells of various depths. He found that a column of water in a well never rose higher than 34 feet. How did Torricelli explain this discovery? Why did mercury rise only to about 30 inches, while water rose to about 34 feet? Who made a water barometer and proved Torricelli's idea was correct?

Does Air Have Weight?

DISCOVER You can find out if air has weight. You will need the following materials for this activity: two identical basketballs, some tape, a yardstick in which you can cut notches, heavy string or twine, a long pole, and two chairs.

Place the pole across the backs of the two chairs, and tie the yardstick from the center of the pole. Move the string back and forth on the yardstick until it is balanced. Use tape to fasten the string on the pole at the point where the yardstick is balanced. Cut two



notches in the yardstick, one inch from each end.

Be sure that each basketball is completely inflated. Tie one basketball to the yardstick at the place where you cut one of the notches. What happens? Why? Tie the other basketball to the opposite end of the stick. When the stick is balanced and straight, you know that the earth's attraction is the same on each basketball. Each basketball has the same amount of matter—leather, rubber, air, etc. Each has the same total mass.

Now deflate one ball. What happens to the stick? Why? Does air have weight? Remove the basketballs from the balance stick.

Does Water Have Weight?

ESTIMATE Take two ½ pint cartons, fill them with water, and tie them to the balance stick. What does the balanced stick tell you about the masses of water in the cartons? Hold a container under one carton. With a sharp pencil, make a hole in the bottom of the carton. What happens to the stick as the water pours out? Does water have weight?

How could you improve your balance stick? How could you estimate the mass in the basketball or carton? A pound is a definite mass which man uses as a standard of comparison. You can make your own standard of comparison. Select some object that has a definite mass, and use this as a measure. A coin, and a pencil, for example, have definite mass. How is the barometer like a balance?

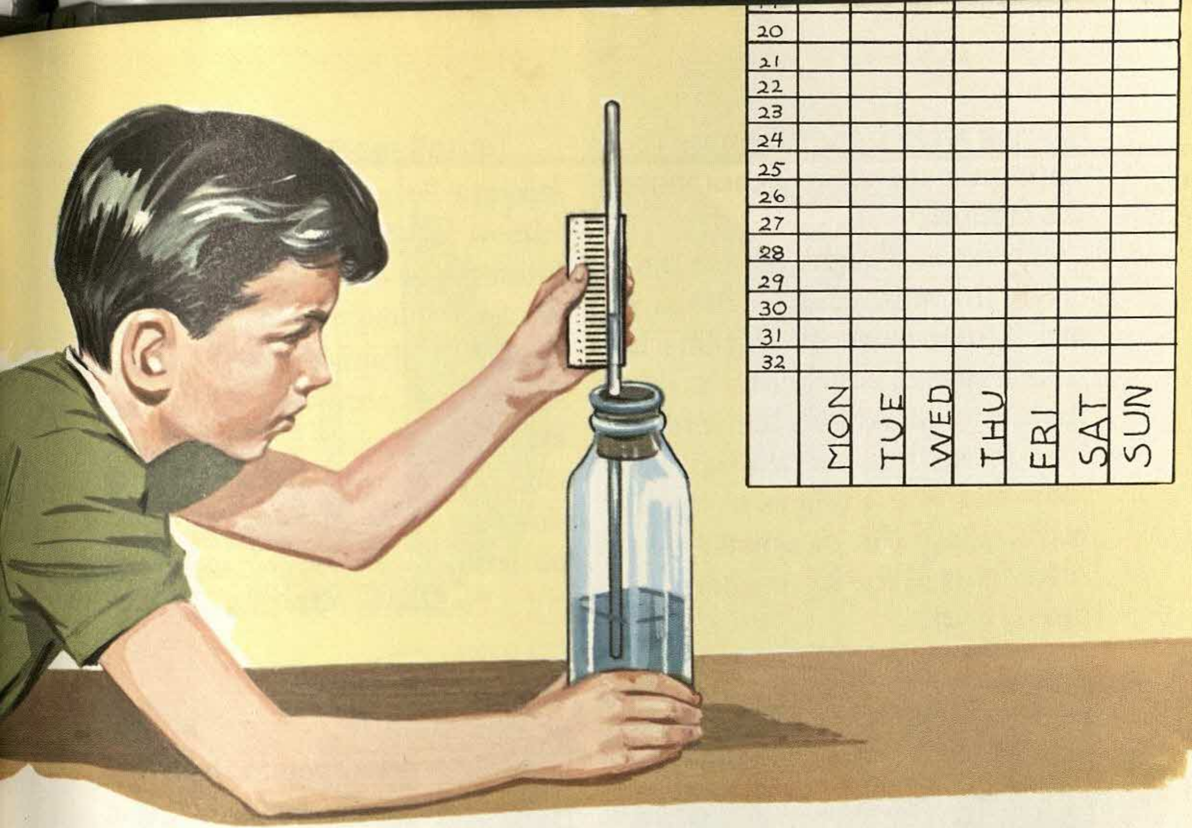
Density

Air and water occupy space and have mass. We measure space by volume, and on the earth we measure mass by weight. The amount of matter in a certain space, a cubic foot, for instance, is a measure called density. Density is, therefore, the weight of a unit volume. Which is denser, air or water? Density helps us to compare matter, for when we determine density, we compare amounts of matter.

How Do Air and Water Differ?

COMPARE Put several uncovered bottles of different shapes on the table. Be sure each is clean and empty. Are the bottles really empty? What is in each bottle? How could you prove this? Can you pour the air out of the bottle?

Fill each bottle with water. What happens to the air in the bottle? What shape does the water have? What shape did the air have? Pour the water from one bottle into a flat container. What shape does the water have in the container? Could you pour a bottle of air into the flat container? How do air and water differ in the way they occupy space? Why was it easier to measure water than it was to measure air?



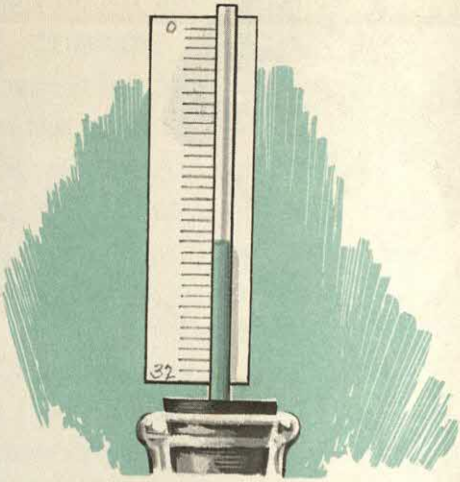
Does Air Exert Pressure?

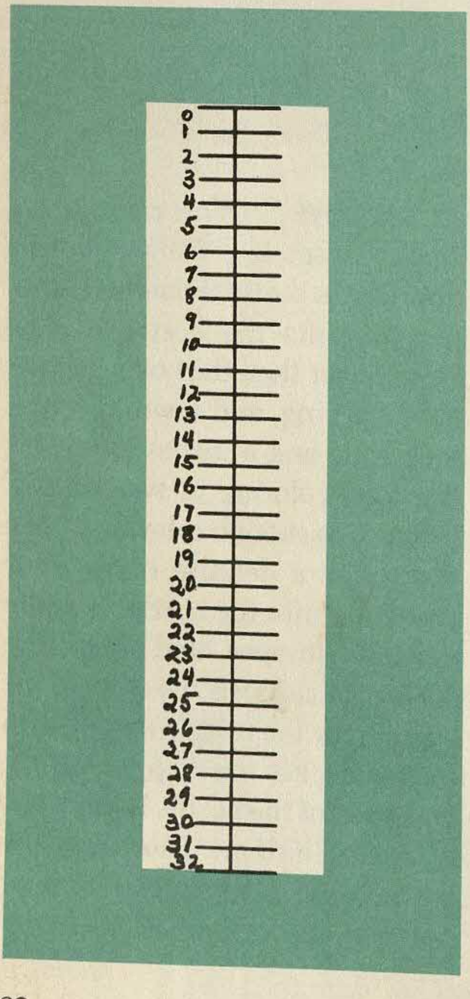
What Does a Barometer Measure?

Torricelli believed that air has weight. How did he measure the weight of air? What is the weight of a column of air which covers one square inch? Torricelli discovered some other things about air as he observed his barometer. One of the things he observed was that the mercury in the barometer was not always at the same height. It changed a little from time to time, or from day to day. Make a list of the reasons why barometric readings change.

OBSERVE You can make a water barometer. You will need a quart glass bottle, a one-hole stopper that fits the bottle, a glass tube longer than the bottle, water, food coloring, and a white card 1 inch wide and 4 inches long. Mix the food coloring in two cups of water. Use enough coloring to give the water a definite color. Pour the water into the bottle. Wet the one-hole stopper, and insert the glass tube through the stopper far enough for the tube to extend into the water. Fix the stopper tightly in the top of the bottle. Be sure the stopper is airtight. Blow into the bottle through the tube. What appears in the water? Why? Keep blowing air into the tube until the water rises about two inches above the stopper.

Draw a straight, 4-inch line across the white card. Use a sharp pencil, and mark off the line in ⅛-inch spaces. Number the marks from 0 to 32. Attach the card to the tube so the 0 is at the top, and the water in the tube is at the 20 mark. Place the barometer in a shady part of the room where the heat is even.





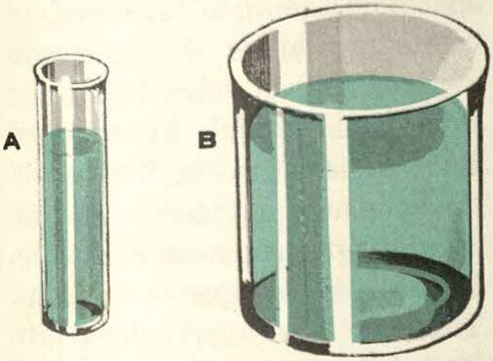
What will happen to the water in the tube if the air pressure in the room increases? What will happen to the water in the tube if the air pressure decreases? Take your reading each day at the same time. Keep a graph of your readings for two weeks.

Draw fourteen vertical lines at equal distances from each other. Draw sixteen horizontal lines across the vertical lines, also at equal distances from each other. Label the lines. On the first day, check the reading on your barometer and mark the graph with a dot where the day-line and pressure-line meet. Join the dots with a straight line.

You have constructed two barometers. Which one do you think is better? Why?

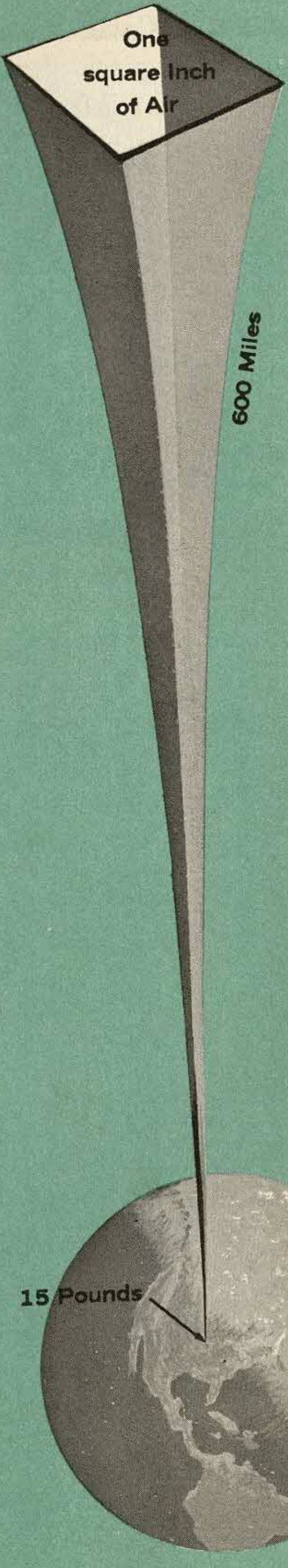
Pressure Differs from Force

The word "pressure" appears frequently in the study of weather. It is important to understand what this word means. Look at pictures A and B. Each represents a container of water. Which column of water do you think exerts the greater pressure on the bottom of the container? Which column exerts the greater force on the bottom of the container?



The total push against a surface is called "force." The force against one square unit of that surface is called "pressure."

Air exerts a total force of nearly 20,000 pounds on a card table. What is the air pressure against the table? When we say that air pressure is about 15 pounds on a square inch, we mean that if you could capture all the air in a long, thin column above this surface of one square inch and weigh it, the air would weigh about 15 pounds.


One square Inch of Air
600 Miles
15 Pounds

DESCRIBE Cover the top of a funnel with a piece of rubber. Use rubber bands to keep the rubber stretched tightly over the top of the funnel. Why is the rubber level? Point the funnel in different directions. Does the rubber remain level? Why? What does this activity tell you?

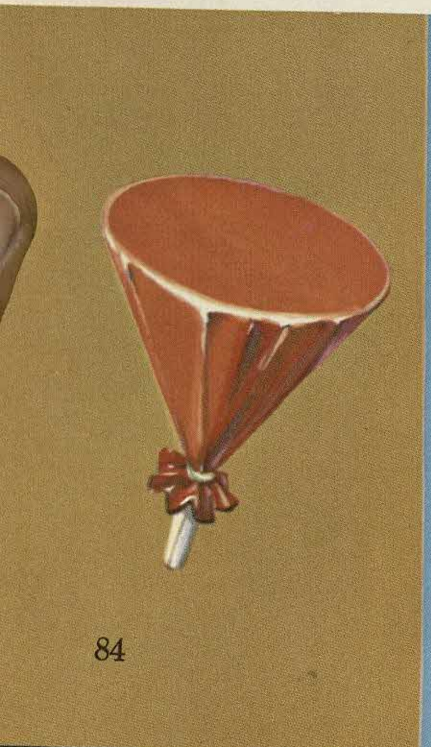
If you suck some of the air out of the funnel, what happens to the rubber? Why? Suck a little air out of the funnel, and cover the end with your finger. How could you test for air pressure?

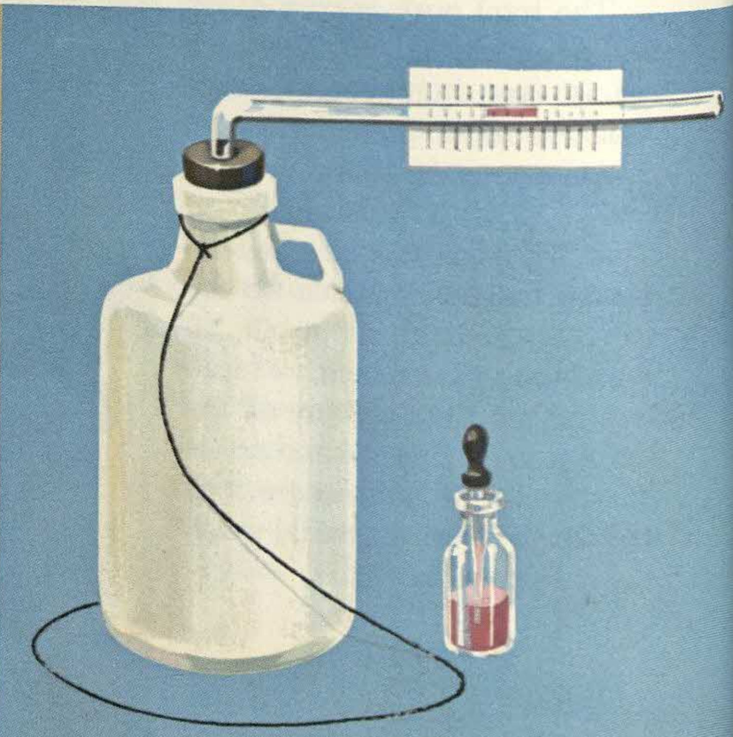
Altitude Affects Pressure

If you took a barometer or your funnel tester up on a mountain, would the pressure of the air be the same as it was at sea level? A barometer can also be used to measure altitude, that is, height above sea level. This kind of barometer is called an altimeter (al-TIM-uh-ter).

ACTIVITY To make an altimeter, you will need a gallon plastic jug, a piece of glass tube bent into an L, an index card, a medicine dropper, colored water, a one-hole stopper, and heavy string.

Draw a line across the middle of the index card. Mark off ¼-inch spaces on the line. Put a drop of colored water in the long arm of the L-shaped tube. Insert the short arm through the stopper. Put your finger over the end of the long arm, and insert the stopper through the mouth of the jug. Be sure the stopper is air-tight. Tape the card to the long arm of the glass tube. Tie the string





around the neck of the bottle, leaving a loop so you can carry your altimeter without touching the bottle itself. What keeps the drop of water inside the glass tube?

Carry the altimeter up to the top floor of your house. What do you notice about the water marker? If possible, carry your altimeter up in an elevator. What happens? Why? □□

Denver, Colorado, is one mile above sea level. Would you expect the air pressure to be greater or less there than at sea level? What would happen to your altimeter in Denver?

Who first showed that the air pressure changes as we ascend in the ocean of air?

Pascal showed that the column of mercury in a barometer is about one inch less for each 1,000 feet above sea level. In a city which is a mile above sea level, what would be a normal reading for a barometer? (A mile equals 5,280 feet.) According to his observations, how high would Pascal have estimated the atmosphere to be?

In 1662, Robert Boyle, a British scientist, showed that this calculated height could not be correct. See if you can discover why Boyle believed the ocean of

air was higher than five miles. Boyle took a glass tube shaped like a "J." He poured a little mercury into the long arm of the tube. When he stopped pouring, the level of the mercury was the same in each arm of the tube. Why? At sea level, what would be the air pressure on each side of the tube?

Boyle then sealed the short arm of the tube with a cork, and made it as air-tight as possible. He poured more mercury into the long arm. What happened to the air in the short arm of the tube? What happened as he poured more mercury into the long arm?

Robert Boyle proved that air could be squeezed together, or compressed. In what part of the atmosphere is the air squeezed together most; that is, where is the air most dense? Why?

Temperature Affects Air Pressure

ACTIVITY Do you believe that you can put a boiled egg into a milk bottle? Air pressure will help you do this.

Use a cool, hard-boiled egg, slightly bigger than the mouth of the bottle. Remove the shell. Tie cotton string around a small piece of paper. Hold the string, and drop the paper into the bottle. Be sure the string is long enough and that it hangs over the top of the milk bottle.

Light the string with a match. As soon as the paper starts to burn, put the egg in the mouth of the bottle.

What happens to the egg? Why was the air pressure greater on the outside of the bottle than on the inside?

How can you get the egg out of the bottle? Tilt the bottle, and blow hard into it.

What happens to the egg as you turn the bottle over?

THINK

Explain why a falling barometer usually indicates bad weather.

Explain what might happen to the weather in Florida if the Gulf Stream changed direction.

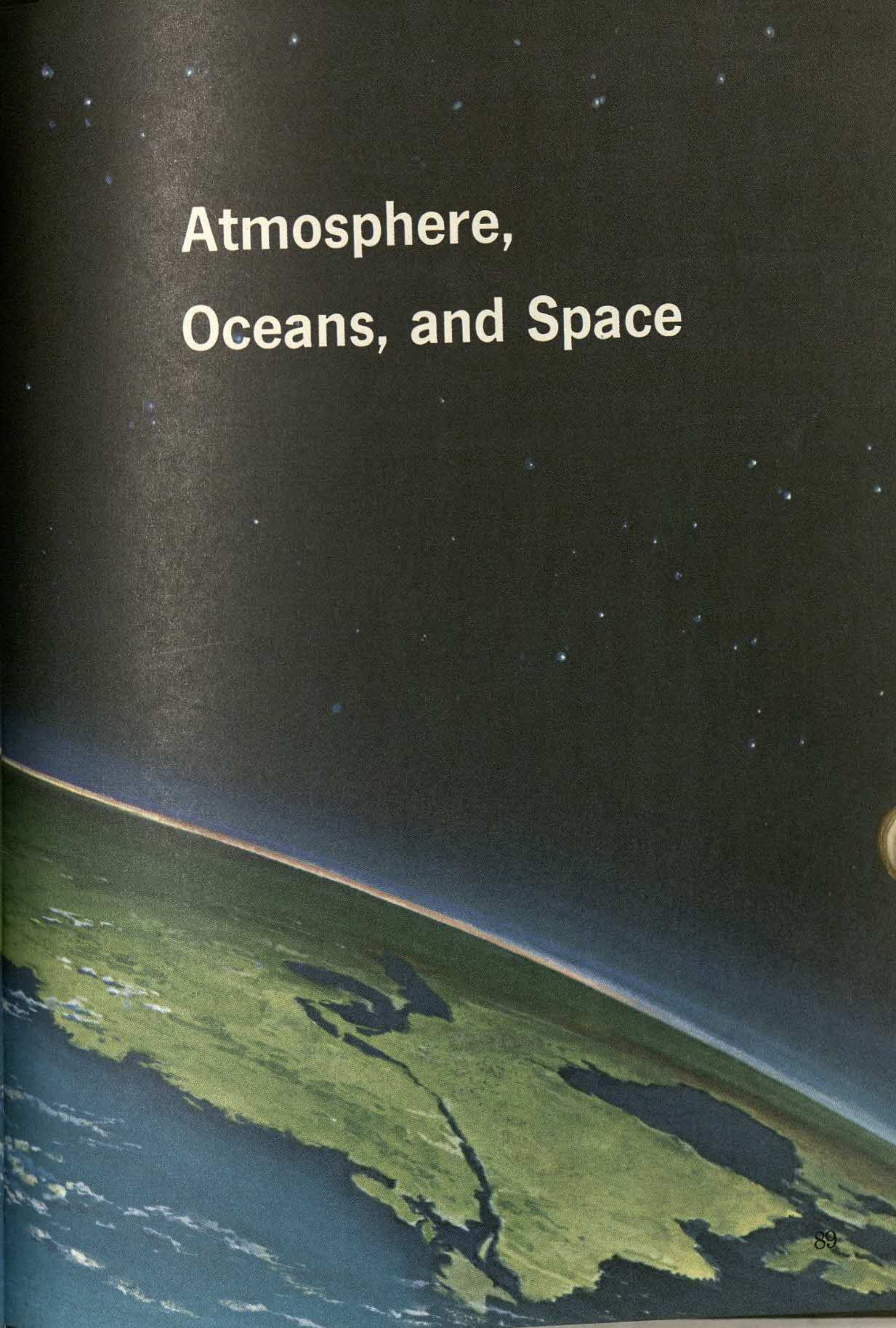
San Francisco is said to be an area which has natural air conditioning. Look at a map and see what factors might account for this statement.

Look at various climate zones and see if this statement is true: Climate affects the mode of life of a people.

Two scientists took a balloon to about 70,000 feet above sea level. When the balloon descended and landed, the scientists were dead. What might be the explanation?

PROJECT

Obtain some cobalt chloride. Dissolve 5 grams of it in 50 cc of water. Soak a piece of filter paper thoroughly in the solution. Allow it to dry on a piece of wax paper. What happens to this paper when it is exposed to moist air? How could you use this type of paper to help you gain information that would let you make better predictions about the weather?



Atmosphere, Oceans, and Space

First Ascents in the Ocean of Air

It was not until 1783 that man was able to ascend in space and explore the air above the earth. In June of that year, two Frenchmen, Jacques and Joseph Montgolfier, attempted to find out if a bag of hot air would rise in the atmosphere.

In a paper factory which they owned, the Montgolfier brothers manufactured a large paper bag that measured about 35 feet through the center. Measure a distance of 35 feet so you will have an idea of the size of the bag. They raised this bag over a fire of straw and wood. When the bag was filled with hot air and smoke, they released it. The bag slowly rose into the air. Do you think this bag stayed in the air very long?

A few months later, the Montgolfier brothers attached a basket, called a gondola, to a balloon. They put a sheep, a rooster, and a duck into the basket, and sent them aloft as the first space travelers. The flight lasted eight minutes. The balloon descended two miles from the launching point, with its passengers unharmed. Why do you think animals were used as the first passengers in a balloon flight? Do you know of any other experiments in which animals were the first passengers?

The First Pioneers

Finally, in November, 1783, the Montgolfiers succeeded in launching a manned balloon, which carried the courageous pas-

sengers, Pilâtre de Rozier and the Marquis d'Arlandes to an altitude of 500 feet. This was man's first adventure away from the earth and into the air above him.

How does a balloon float in the air? Which weighs more, a bag containing hot air or a bag of the same size containing cold air? Is there greater pressure on the outside or on the inside of the lighter bag? Which force will be greater, the force of gravity pulling the balloon of hot air down, or the upward push of the cooler air on the outside of the bag?

Just two months after the Montgolfiers successfully launched the first manned balloon, another Frenchman, Jacques Charles, decided to experiment with balloons. He constructed a balloon, but instead of filling it with hot air, as the Montgolfiers had done, Charles used a new gas. This gas had been discovered seventeen years before, in 1766.

In that year, a British scientist named Henry Cavendish announced that he had discovered a gas he thought was about one tenth as heavy as an equal volume of air. He called this gas "inflammable air" because it burned so easily. Today we call this gas hydrogen, and we know that it is one thirteenth as dense as air.

Hydrogen Aids the Pioneers

In 1776, Joseph Black of Scotland proved that this new gas, hydrogen, being lighter than air, enables objects to rise. Why would this gas enable objects to rise? Guests at Joseph Black's home were often entertained by a hydrogen demonstration. Black filled calves' bladders with hydrogen, released them, and enjoyed his guests' expressions of surprise when the bladders rapidly rose to the ceiling.

Knowing what hydrogen was capable of doing, Jacques Charles thought of using hydrogen in his balloon. He manufactured a silk bag shaped like a globe, and lined the inside of the bag with gum to keep it well sealed. Why was it necessary for the balloon to be well sealed? The balloon was about thirteen feet through the center. Professor Charles had the balloon carried out to a large field in Paris where it was filled with hydrogen.

Crowds of people gathered to watch. The ropes were cut and the balloon rose rapidly into the air. The people watched the hydrogen-filled balloon ascend into the clouds. For an hour they watched as the balloon kept appearing and disappearing.

The peasants in a village about fifteen miles from Paris were ter-

rified by a huge ball that came dropping out of the heavens. They ran for guns, pitchforks, and stones, preparing to attack this monster from the sky. Why do you think these people were so frightened?

The balloon had traveled about fifteen miles over the surface of the earth, but it had ascended so high in the ocean of air that it split. Why did the balloon split? As the balloon ascended in the atmosphere, what happened to the air pressure on the outside of the balloon?

DISCOVER You will need a gallon jug, a one-hole stopper to fit the jug, a piece of glass tubing 10 inches long, a piece of rubber tubing that fits tightly over the end of the glass tube, a piece of string, a balloon, and a clip clothespin. Blow up the balloon a little, tie it, and squeeze it into the jar. Why is it possible to squeeze the balloon into the jar? Fit the glass tube into the stopper. Attach the rubber tubing to the glass tube, and tighten the stopper in the mouth of the jug.

Suck air out of the jug. Use the clothespin to squeeze the rubber tube together when you stop for breath. Keep sucking out the air. What happens to the balloon? Why? Should a balloon be completely inflated before it is released in the atmosphere? □□

Four months after Jacques Charles sent the first hydrogen-filled balloon into the air, he himself ascended in a basket, which was suspended underneath a balloon. Charles was accompanied in the basket by one of the men who had helped construct his first balloon. The balloon itself had two valves, one at the top and one at the bottom. The two passengers hoped to use these valves to control the ascent and descent of the balloon. Charles carried a barometer and a thermometer with him to check the pressure and temperature of the air.

This flight was a great success and the landing was skillfully accomplished, but just as Charles' companion stepped out of the basket, the balloon shot into the air again with Charles aboard! Can you explain why this happened? Charles ascended over a mile before he could control the balloon again.

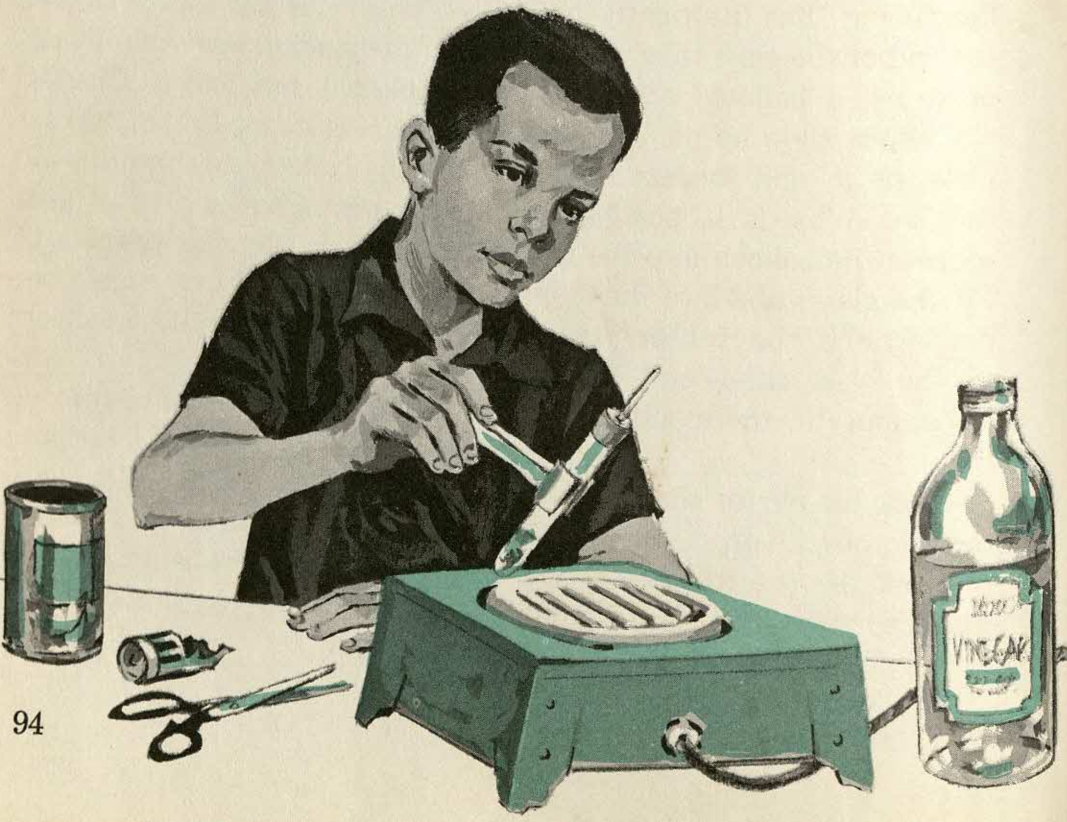
What do you think he discovered about the ocean of air at the height he had reached? Remember, Charles was in an open basket suspended from the balloon. What kind of ride do you think he experienced?

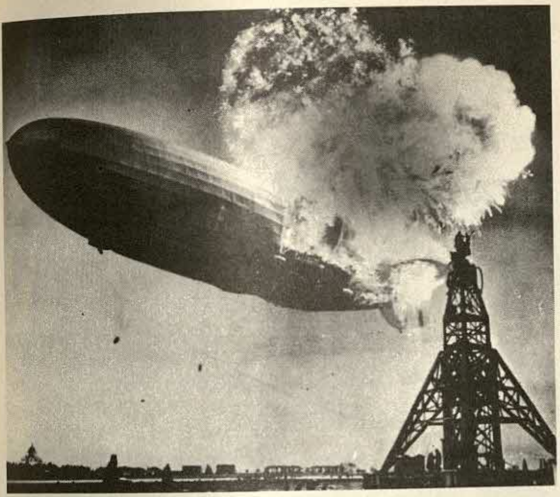
What Is Hydrogen?

DISCOVER You can make hydrogen. Your teacher will help you. *Hydrogen is dangerous, and should be prepared only with your teacher's help.* You will need an old flashlight cell for zinc, vinegar, a test tube, a test tube holder, a one-hole stopper for the test tube, a glass tube as long as the test tube, a hot plate, and a wood splint.

With sharp shears, cut out a piece of the zinc can of a flashlight cell. Cut the zinc into small pieces and drop them into the test tube. Cover the zinc with about one inch of vinegar. Insert the glass tube through the stopper so that the tube is about an inch above the liquid. Place the test tube in the holder, and gently heat the tube; keep moving the test tube slowly back and forth over the hot plate. Whenever you heat a liquid in a container, *always* keep the container pointed away from your face. When the liquid begins to boil, be sure that none of the vinegar enters the tube. Remove the test tube from the hot plate, and let it cool for five minutes. Stand the test tube in an empty can to cool. Do not remove the stopper.

After five minutes shake the tube, but *keep the tube slanted away from your face.* Light a





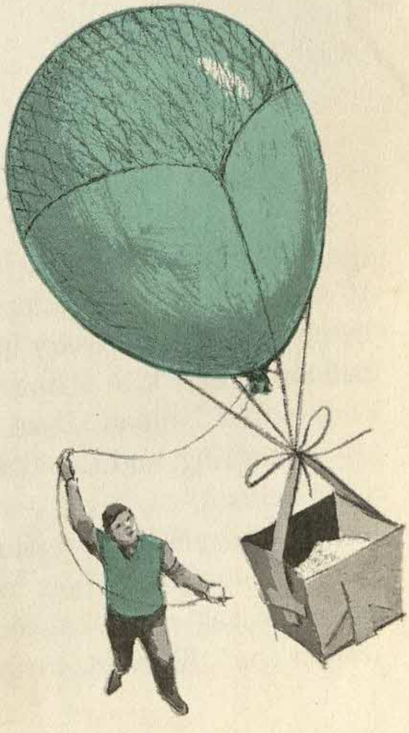
Explosion of the Hindenburg.

wood splint, remove the stopper, and quickly lower the splint into the tube. The gas will pop! The colorless, odorless, and tasteless gas that pops when a flame is brought near it is hydrogen. ☐☐

Hydrogen gas is very light in mass as compared to an equal volume of air. Hydrogen is therefore less dense than air, and will escape from the tube into the air. Hydrogen gas is the least dense matter known to man. Why is it unsafe to use hydrogen in balloons?

During the early part of this century, some motor-driven airships built like balloons were manufactured in Germany. These airships, in which hydrogen gas was used, were called dirigibles. One dirigible, called the Hindenburg, made many trans-Atlantic flights. On May 6, 1937, the Hindenburg exploded as it prepared to land at Lakehurst, New Jersey. Thirty-six persons were killed. Since that time hydrogen has not been used for any lighter-than-air craft.

ACTIVITY If you can obtain a commercial toy balloon, you can watch a balloon flight. You will need a balloon that has been inflated with a gas that is lighter than air. You will also need a hair net big enough to cover the top of the balloon. Make a paper or wire basket; use string to attach the basket to the hair net. Add some weight to your basket (sand will do). This weight is called ballast, and is used to help control



the flight upward. You will have to experiment to find out how much ballast is necessary for your balloon. Tie a kite string to the end of the balloon. Hold on to the kite string, and slowly launch your balloon.

A hydrogen balloon can carry twelve pounds of weight for each pound of gas in the balloon. The weight that the balloon can carry is called the payload. What is your balloon's payload?

Watch the balloon as it ascends. What can you discover about the way air moves? Do you think the early explorers of the ocean of air had a very smooth or safe ride?

Balloons as "Laboratories"

After the successful flights launched by the Montgolfier brothers and Jacques Charles, many balloon flights were tried. Some were successful, but others failed. An American physician, John Jeffries, made a balloon flight over London with a barometer and other instruments. He wanted to determine the pressure, temperature, and humidity of the air. During his ascent, Jeffries collected samples of the air at different levels.

By the early nineteenth century, men had ascended to a height of 4½ miles in the atmosphere. Traveling in open baskets, they measured the temperature, pressure, and density of the atmosphere. They found, however, that they could go no higher than 4½ miles because, as they ascended, it became more and more difficult to breathe. What elements in the air are essential for breathing?

What Is Air?

"Fixed Air"

In January of 1774, a French scientist named Antoine Lavoisier (1743-1794) published a report in which he reviewed all that was known about air. Earlier, in 1756, Joseph Black had reported that a peculiar kind of air resulted from burning and breathing. He also discovered its presence over vats of fermenting beer. He called it "fixed air." In his report of 1774, Lavoisier mentioned that he had repeated Black's experiments on "fixed air." What was this "fixed air"? Let's find out.

DESCRIBE You will need some limewater from the drug store. Pour the limewater into a glass to the height of about one inch. Exhale through a soda straw into the limewater. What happens to the limewater?

DISCOVER You will need a milk bottle, a short candle, a wire coat hanger, and limewater. Cut a piece of wire from the coat hanger. Make a loop of wire around the candle, and lower the candle into the bottle. Bend the wire at the top of the bottle so you have a wire handle with which to lift the candle out of the bottle. Remove the candle from the bottle. Pour enough limewater into the bottle to cover the bottom. Light the candle, and slowly lower it into the bottle. What happens? Why? Leave the candle and the jar undisturbed for a few minutes. Observe the surface of the limewater. Remove the candle. Cover the bottle and shake it. What color is the limewater? ☐☐

When limewater turns milky or cloudy, carbon dioxide is present. This is the gas Joseph Black called "fixed air." You can also produce "fixed air."

DESCRIBE You will need a wide-mouth gallon jar, ½ cup of baking soda, ½ cup of vinegar, ½ cup of water, a candle, wire, a small pill bottle, and limewater.

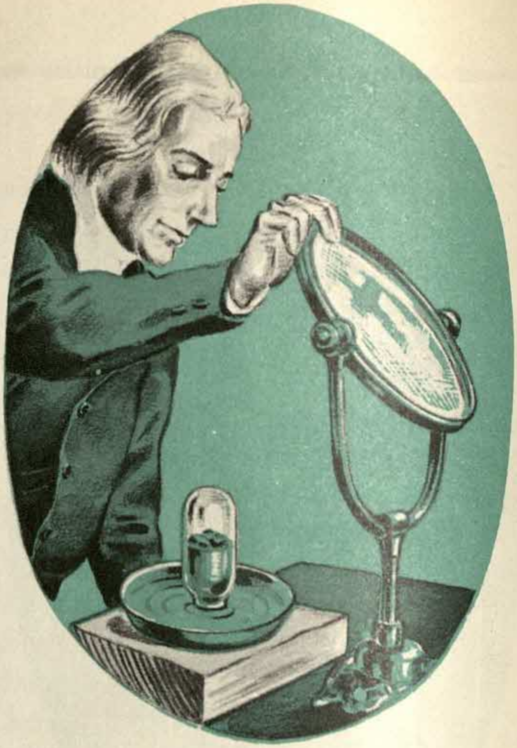
Pour the ½ cup of baking soda into the clean, dry, gallon jar. What happens? Pour the limewater into the small pill bottle. Use the wire to lower the bottle of limewater into the jar. Let the bottle hang for a few minutes in the jar. What do you observe? What are the bubbles of gas? Light the candle, and lower it into the jar. What happens? ☐☐

Carbon dioxide is present in the air. Where do you think there would be more carbon dioxide—in a crowded auditorium or outdoors? Why do you think that the amount of carbon dioxide in the air is not always the same?

"Pure Air"

About the same time that Lavoisier was experimenting in France, another scientist was doing similar experiments in England. Joseph Priestley (1733-1804) was also interested in different kinds of "air."

Priestley made a sparkling water by pouring regular drinking water from one glass to another through a nine-inch layer of "fixed air." The "fixed air" he used for his experiment was present over a vat of fermenting beer.



Through his experiments, Priestley discovered a new substance. He called this new gas "pure air." In this air a candle burns with a very bright flame, and a glowing piece of wood bursts into flame.

Priestley also discovered that small animals like mice live much longer in a container of "pure air" than they do in a container of "common air."

Priestley first discovered "pure air" when he heated a red powder which we now call red oxide of mercury. He heated the red oxide of mercury by focusing sun-

light on it through a very large lens. Many other scientists had experimented with red oxide of mercury, too, but Priestley was one of the first to actually collect the "pure air" for study.

Priestley visited Lavoisier in October of 1774, and described his experiments to the French scientist. Lavoisier was very interested in Priestley's experiments because he was beginning to suspect that air was made up of many gases.

Lavoisier continued to experiment and discovered that when lead or tin is heated to a very high temperature in a closed vessel, the lead or tin gains weight. This weight is equal to the weight the air in the container loses. He reasoned that the metal had combined with one of the gases in the air. This gas, which made up about ⅕ of "common air," was the same gas that Priestley had called "pure air."

Different Gases in Air

In 1779, five years after Priestley's discovery, Lavoisier published his report and named "pure air" oxygen. The remaining ⅘ of "common air," he called nitrogen. You can make oxygen and nitrogen.

ESTIMATE You will need a pyrex baby bottle, a cardboard cover for the bottle, 3-5% hydrogen peroxide, and pieces of activated charcoal. Put a heaping teaspoonful of the charcoal in the bottle. Cover the charcoal with hydrogen peroxide. Cover the bottle with the cardboard. What happens?

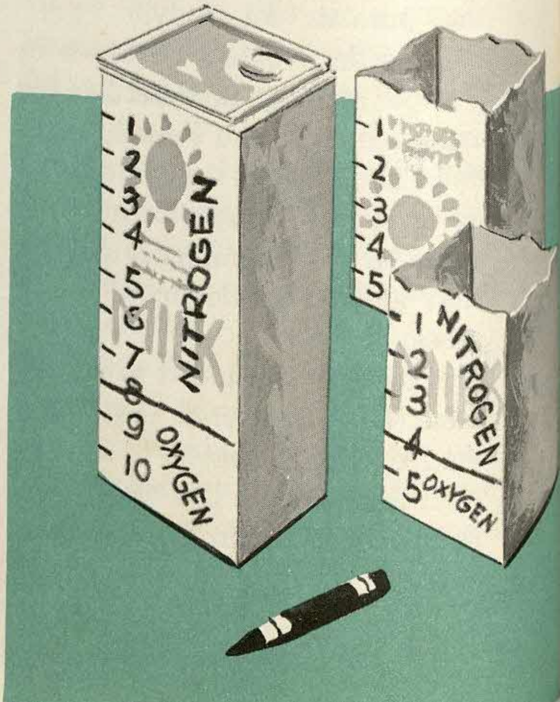
After a few minutes, light a wood splint, and then blow it out. Lower the glowing splint into the bottle. What happens? Why are there NO SMOKING signs in places where oxygen tanks are used? What do you think would happen if more than ⅕ of the atmosphere were made up of oxygen? Why?

TEST You will need some steel wool, a tall glass jar, and a shallow pan of water. Wash the steel wool in a detergent solution. Pack the steel wool into the bottom of the jar. Turn the jar upside down in the pan of water. Mark the level of the water in the jar. Measure the height of the jar above the water. Record the height, and call it A. Let the jar stand in the water for a couple of days. Observe the water level. On the second day, mark the level of the water in the jar, and measure the height of the bottle above the water level. Record this height, and call it B. What part of A is B? $B/A = ?$

Cover the mouth of the bottle and remove it from the water. Look at the space above the water. It looks empty, but it contains the gas which Lavoisier called nitrogen. Nitrogen will not ignite a glowing piece of wood, nor turn limewater milky, nor pop like hydrogen. Yet all the gases which produce such different results are impossible to tell apart simply by looking at them. Scientists would have to make tests to distinguish one gas from another.

Joseph Black of Scotland, Joseph Priestley of England, and Antoine Lavoisier of France, as well as many other men of their time, were the first to discover what air is. These men helped to found a new science called chemistry.

ACTIVITY Take a milk carton, a ruler, and a colored pencil. What is in the carton? Measure



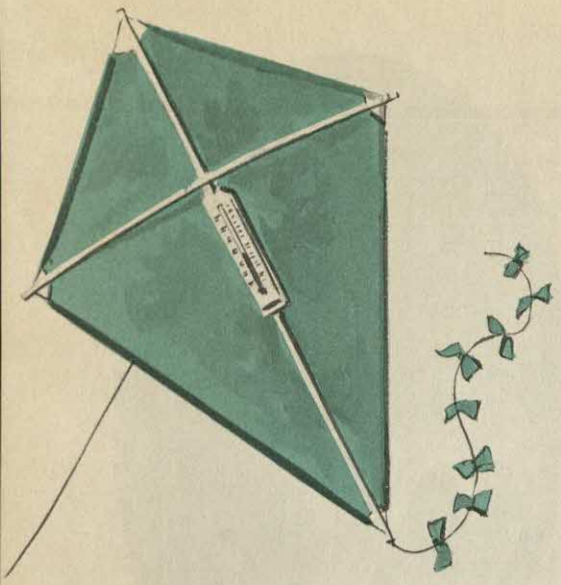
the height of the carton, and mark it off into ten equal parts. Make the line at the top of the eighth part black. Color the carton below this line. The air in your carton consists of 8 parts of nitrogen gas, 2 parts of oxygen gas, and a little carbon dioxide and water vapor, shown by the black line. There are also very small amounts of some other gases, and some dust particles.

Cut your milk carton in half. Do you have as much oxygen as you had before? Now one part is oxygen, and four parts are nitrogen with a little of the other two gases still present. Oxygen is still one part out of five equal parts, but the amount of air is less. So it is as we ascend in the atmosphere. The fractional parts of the air remain the same, but there is less air in each part, for the air is less dense. Why could man, in an open basket of a balloon, not travel much higher than 4½ miles into the ocean of air?

Man Attempts to Ascend Higher in the Ocean of Air

In 1804, Joseph Gay-Lussac (1778-1850), a French scientist, ascended in a balloon to a height of about 4½ miles. In the city of Paris the temperature was 82°F, but at an altitude of 4½ miles above Paris, the thermometer in the basket of the balloon registered 14.9°F. Gay-Lussac collected a sample of the air at this height. It was found to be much less dense than a sample of the air closer to the earth. However, the percentage of each substance in the two samples of air was the same.

About sixty years after Gay-Lussac's flight, a British scientist named James Glaisher ascended to an estimated height of 7 miles. At a height of about 5½ miles, however, Glaisher lost consciousness. At this height, there is too little oxygen to supply a man's



needs. There isn't even enough pressure to force air into the lungs.

It seemed that a limit had been reached in man's exploration of the ocean of air. Man could not travel farther in an open basket.

About 40 years before the Montgolfier's first balloon flight, man had explored the upper layer of air by using kites. As early as 1749, Dr. Alexander Wilson of Glasgow, Scotland, sent a thermometer up by kite. If you live near the shore or in the country, you can find out what Dr. Wilson discovered.

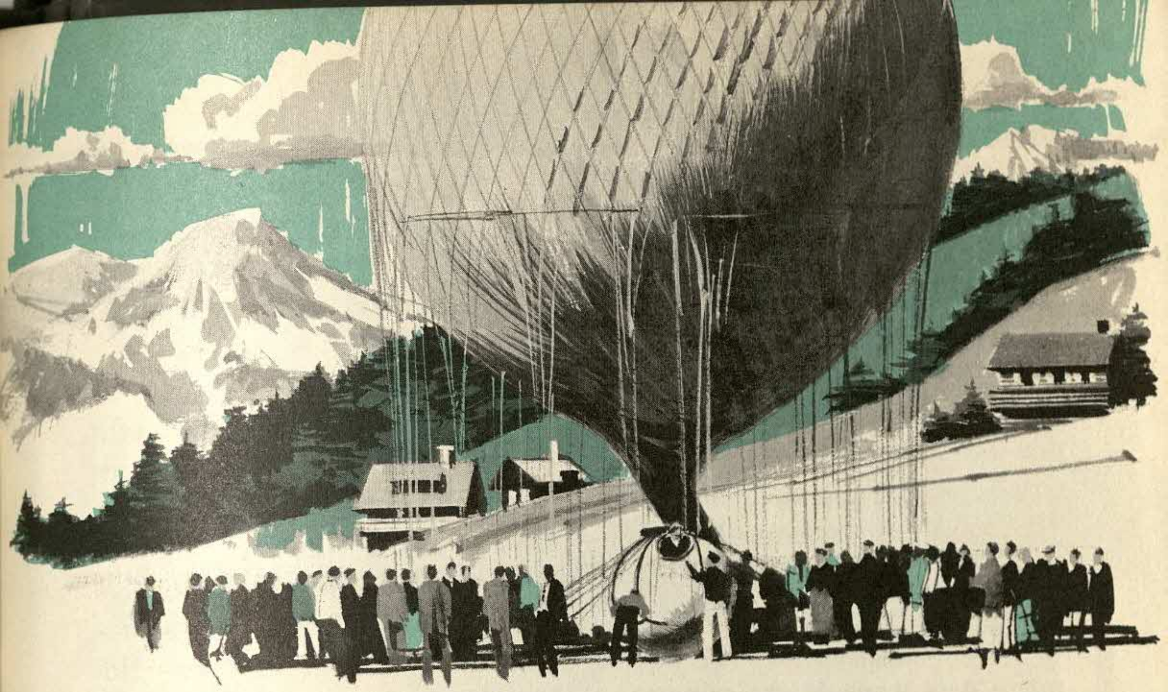
DISCOVER Tie a thermometer to a large kite. On a breezy day, sail your kite as high as possible. Watch the way the kite moves. What does the movement of the kite tell you about the air currents?

After half an hour, pull your kite in as quickly as possible. Compare the temperature reading of your kite thermometer with the temperature on the ground. □□

In the late nineteenth century, the French discovered a way to explore the atmosphere at altitudes higher than 5 miles. New instruments which automatically recorded changes in temperature and air pressure were sent up in unmanned balloons. Since it was necessary to recover these instruments once they dropped to the ground, scientists followed the balloons on foot or horseback. Though they tried to keep them in sight at all times, many instruments were lost.

From those instruments that were recovered, scientists learned that the temperatures recorded by the instruments generally decreased as the instruments rose. Readings from an altitude of 7 miles, however, showed that the temperature at that altitude remained fairly constant at −67°F, and that the air was calm and dry.

In 1900, a Frenchman named Léon Teisserenc de Bort suggested that the atmosphere was made up of two layers: a lower layer in which clouds, storms, and winds are present, and an upper layer of calm, dry, cold air. He



called the lower layer the "troposphere," and the upper layer the "stratosphere." The boundary between the troposphere and the stratosphere he called the "tropopause."

New Instruments - New Frontiers

The twentieth century brought new knowledge, materials, and methods which enabled man to ascend higher in the stratosphere. New light metals made it possible to build a sealed gondola strong enough to be carried by a balloon into the low pressure of the upper atmosphere. In 1931, Auguste Piccard (1884-1962), a Swiss scientist, ascended in a sealed metal gondola into the stratosphere to the height of 51,775 feet. How many miles is that?

By the end of the 1930's manned balloons had reached a new frontier of thirteen miles. Unmanned balloons had reached heights of over twenty miles. At

Start of Piccard's record altitude flight.

this height the air is very thin, so the upward push, or buoyancy, of the air is slight. In order to support a gondola in this thin air, manned balloons would have to be made larger. But what happens to the mass of the balloon when its size is increased? Man faced a new problem. Again scientists turned to unmanned balloons. Why would an unmanned balloon ascend higher than a manned balloon?

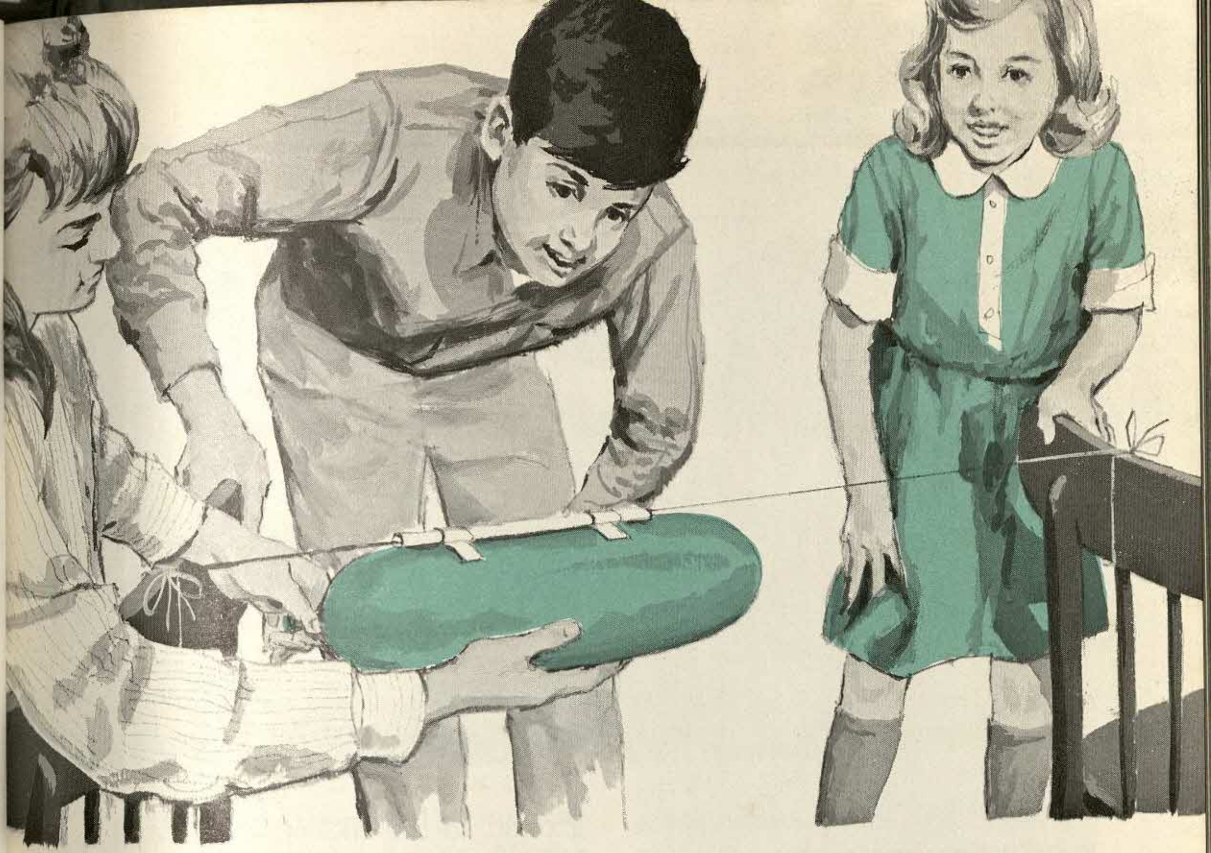
The invention of the radio made new ways of exploring the atmosphere possible. In 1925, a Russian scientist, Pyotr A. Molchanoff, used the radio to send coded messages of the temperature, pressure, and humidity of the air. This information had been recorded at various altitudes by instruments in unmanned balloons. This method of gathering information is called telemetering. Balloons that send coded radio messages of the conditions of the atmosphere are called radiosondes.

The first radio apparatus was large and clumsy. Compare the size of a radio of 25 years ago with a radio of today. It was the search for smaller equipment for space exploration that quickened the change in size.

Little by little, man reached new frontiers in the ocean of air. The use of new plastic material thinner than this page, and smaller electronic equipment made possible lighter balloons.

Rockets

In the meantime, a new method of exploring the ocean of air was being developed. At the beginning of this century, two men, an American and a Russian, became interested in an old idea—rockets. The American was Robert H. Goddard (1882-1945) of Worcester, Massachusetts. The Russian was Konstantin E. Tsiolkovsky (1857-1935), a high-school mathematics teacher.



In March, 1926, Robert Goddard fired a rocket 200 feet into the air. Unfortunately, his work was not noticed except by his neighbors, who demanded that he move his experimenting elsewhere. Between that date in 1926, and the year of his death in 1945, Goddard developed the systems and controls that are the basis of modern rocketry.

DISCOVER Blow up a balloon. Release it. What happens? Blow it up again. In what direction does the balloon move when you release it? Does it move in the same direction as the escaping air, or in the opposite direction?

Get a long balloon and blow it up. Tape a soda straw lengthwise to the balloon. Now pass a thin wire through the straw. Fasten the ends of the wire to two chairs so your balloon is suspended. Pull the balloon to the starting point. Release the air from the balloon. What happens? How was your first rocket flight? ☐☐

When hot gases rush out of the end of a rocket, the rocket is pushed forward in the opposite direction. Three hundred years ago, Isaac Newton (1642-1727) explained this law of motion: to every action there is an equal and opposite reaction.

MEASURE If possible, get a toy plastic rocket that can be fired by compressed air and water. Read the directions carefully, and practice a few shots before you begin the activity. Be sure to do the activity in an area where your rocket landing will be on grass or loose dirt. Why?

The rocket is filled with water, and air is forced into the rocket by an air pump. When the rocket is released, the compressed air and water rush out the open end of the rocket. In what direction does the rocket move? What law of motion is being demonstrated?

Hold the rocket so that its nose is lined up with the ground. Measure the distance from the ground to the rocket. Pump and count the number of strokes you use. Fire. Mark the place where your rocket landed. Measure the distance. What was the path of your rocket?

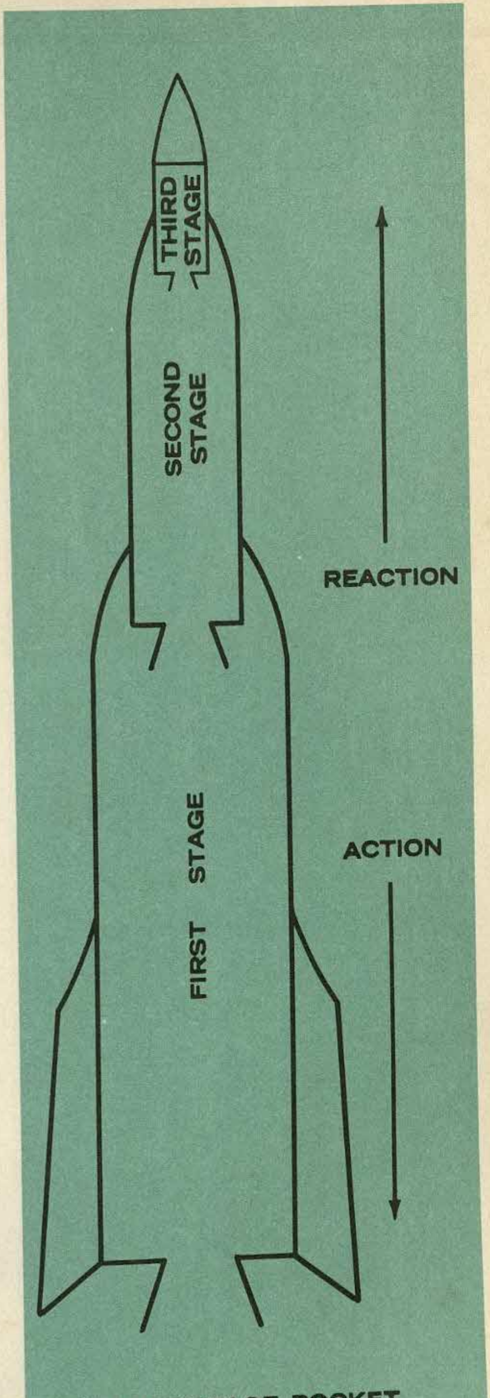
Reload the rocket and hold it in the same position, but increase the number of strokes. Fire. Mark the landing place. Was the path of your rocket the same?

What do you predict would happen if you could increase the push on the rocket ten times?

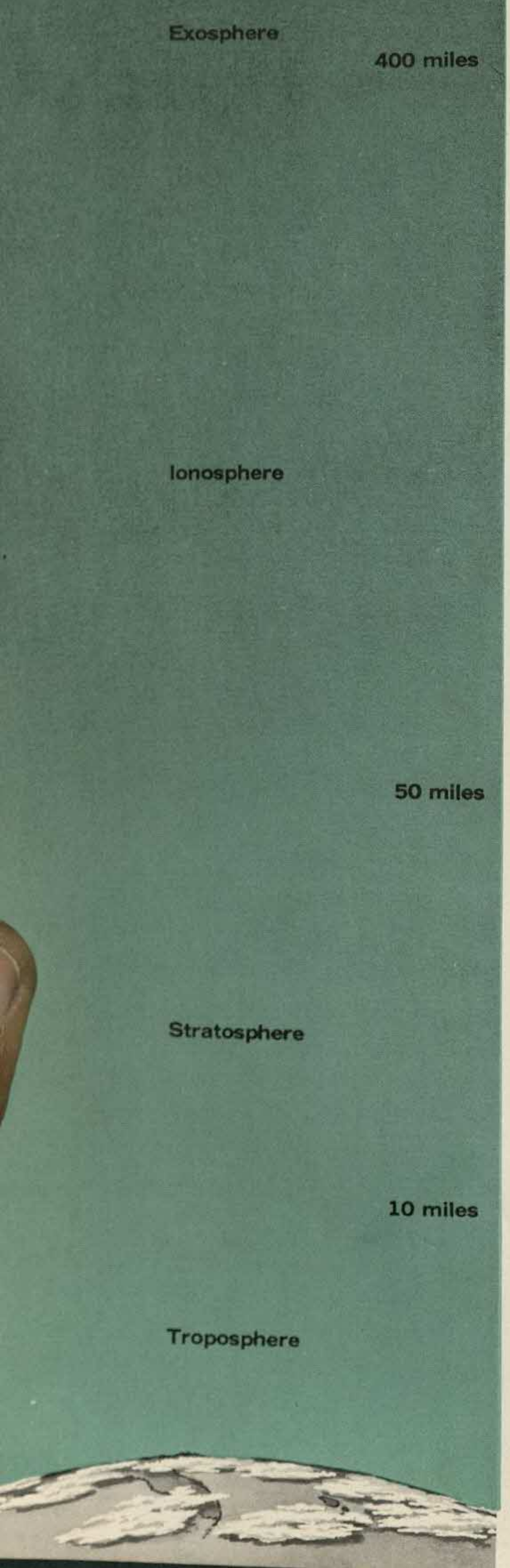
Launch the rocket from a second floor window. What is its path? What do you predict would happen if you could launch your rocket from a ladder that reached a mile or more into the atmosphere? Explain your answer. □□

In the 1950's man used a balloon as his "ladder." A small rocket, fastened to a balloon, was carried to the height of about twenty miles. Then the rocket was fired by remote control from the ground. The balloon-launched rocket is called a rockoon and is used for upper atmospheric study. Is the air pressure as great at a height of about twenty miles as at sea level? Is the air as dense at twenty miles as at sea level? Would the horizontal speed of a rocket fired from a balloon at an altitude of twenty miles be greater than, less than, or the same as that of the same rocket fired in the lower atmosphere? Why?

The bigger the payload and weight of the rocket, the greater must be the push of the exploding gases. The upward push is called the thrust. What is the downward pull of the earth called? To raise a big payload, a rocket of many sections is used. Such a rocket is called a multistage rocket. The first stage carries the rocket out of the lower atmosphere. When the fuel in each stage is used up, that section is dropped. When the rocket reaches a planned altitude and position, the last rocket is fired, thrusting the payload into orbit.



MULTISTAGE ROCKET



Beyond the Atmosphere

The use of rockets and telemetering shows that there are layers within the stratosphere and other layers beyond the stratosphere. The lower stratosphere is cold and clear. Here are the high winds called jet streams. The temperature in the stratosphere remains fairly constant below the height of 30 miles (about −67°F). At an altitude of 30 miles, temperatures rise to 30°F, almost to the freezing point of water. At an altitude of 50 miles, near the upper limit of the stratosphere, the temperature drops to −90°F, far, far below the freezing point of water.

The particles of air beyond 50 miles are electrically charged and are called ions. This region is called the ionosphere. Sections of this layer act like mirrors for some radio communication, bouncing the radio messages back to earth. The ionosphere extends from 50 to about 300 miles above the earth's surface. Temperatures in the ionosphere rise as altitude increases, reaching 2,000°F. Beyond the ionosphere is the exosphere, where temperatures continue to rise.

Are these regions the same around the earth? Are they the same over the poles as over the equator? Are they the same in winter and in summer? Is there more than one jet stream?

A world-wide scientific study was begun in July, 1957, to find the answers to these and many other questions. This study was called the International Geophysical Year, or IGY. It lasted until December 31, 1958. For eighteen months, 60,000 scientists from 66 nations worked in teams all over the world to explore the oceans of air and water and the earth itself. New answers have brought new questions, and man still strives to search farther and deeper into the ocean of air.

Exploring the Exosphere

The Soviet Union launched the first manned satellite into orbit on October 4, 1957. A new era of exploration had begun. The United States and the Soviet Union have been the pioneers in this exploration. In 1961, man became a space traveler orbiting the earth. What conditions of the lower atmosphere must man take with him into the exosphere?

Radio, telemetering, rockets, plastic balloons, rockoons, television, and satellites now provide new ways to explore the vast ocean of air that surrounds our earth. Thousands of people are working together to find answers to new and old questions. The spirit of inquiry that urged the first balloon passengers to ascend in this ocean still urges man to seek new knowledge.

We Explore Our Oceans

Since the time of Torricelli, much has been learned about the ocean of air that surrounds the earth. What has been learned about the oceans of water on the earth? Water covers about three-fourths of the earth's surface. How have these oceans of water been explored?

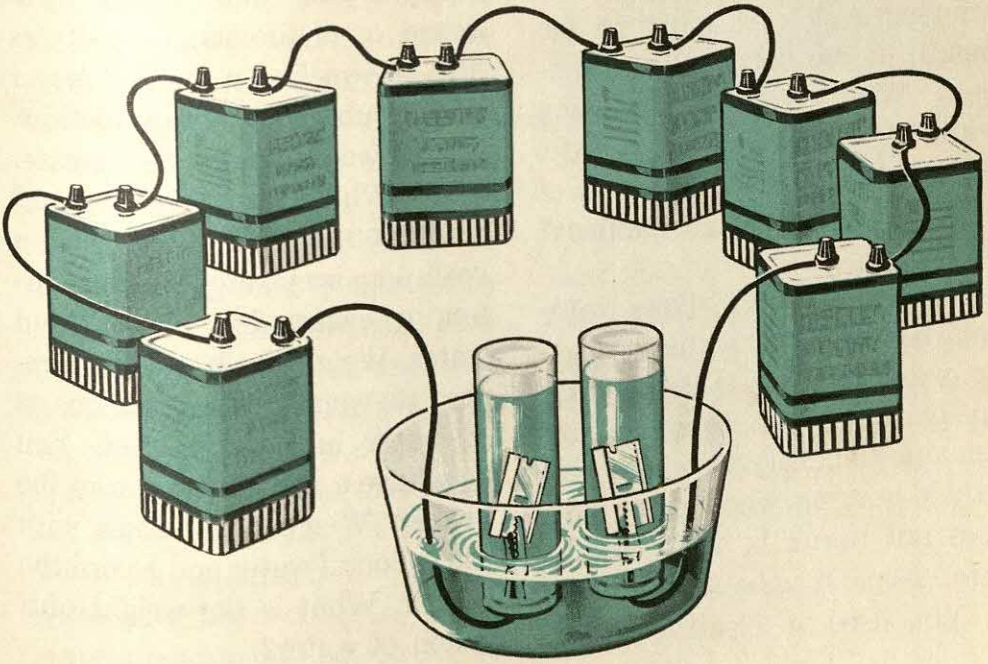
OBSERVE Place a glass of water on the table before you. Make a list of all the things you know about water. The picture on this page will help you.

Remember that air is a mixture of gases. The tiniest particles of any gas, liquid, or solid are called molecules. Air contains molecules of nitrogen, oxygen, carbon dioxide, and water vapor. Water is a liquid. Is water a mixture of different liquids?

ACTIVITY You will need two tall pill bottles, a jar of water, 8 No. 6 dry cells, insulated bell wire, two single-edge razor blades, two alligator clamps, and sodium sulfate.

Connect the 8 dry cells in a series, as shown. Cut seven pieces of wire, and scrape about an inch of insulation off each end. Connect a (+) pole of a cell to a (−) pole of the next cell by bending the noninsulated piece of wire around the pole, and then tightening the screw. Cut two eight-inch pieces of wire and scrape off the insulation at the ends. With a screw, connect an alligator clamp to one end of each wire. Connect the other end of each wire to the unused pole of the first and last cells. Now clip a razor blade in each alligator clamp.

Dissolve as much sodium sulfate as you can in the jar of water. This solution will conduct electricity. Fill both pill bottles with water. Cover each bottle with your thumb, and place it, mouth down, in the solution in the jar. Place a razor blade under each bottle.



What do you notice? Under which bottle is the wire from the negative pole? Note the number of bubbles in this bottle compared with those in the other bottle. The gas being collected in this bottle is hydrogen, the other oxygen. Where are these two gases coming from?

When one bottle is filled with gas, the other should be about half filled. Remove the bottles from the solution, one at a time, remembering to cover the mouth of each bottle with your thumb. Why must you do this? Place each bottle, mouth down, on the table. Now you are ready to test for the gases.

Test for the oxygen by slightly lifting the half-filled bottle, and bringing a glowing splint to the mouth of the bottle. What happens? Why? Do the same thing with the hydrogen-filled bottle, using a lighted match instead of a glowing splint. What happens? Why?

Does water burn? Does water help burning? Yet water is made up of two parts of hydrogen and one part of oxygen. How is hydrogen able to burn and oxygen able to help burning, when water itself does not burn? Is water a mixture? Explain your answer.

You used an electric current to separate water into the two gases, oxygen and hydrogen. The union of oxygen (O) and hydrogen (H) to form water is written as H_2O. Why?

Water Exerts Pressure

A gas like air can be compressed. When you compress a gas, you increase the density of the gas. Where is the air on the earth the densest?

We live at the bottom of the ocean of air. Think of the oceans of water on earth. Where do we live in relation to these oceans?

Water Has Weight

Is water more dense, less dense, or of the same density as air? If you had a cube of water and a cube of air the same size, which would have the greater mass? Which would weigh more?

MEASURE You will need a bathroom scale, a quart milk carton, a clean, dry bucket, and water. Weigh the bucket and record its weight. Pour four quarts of water into the bucket. You now have a gallon of water in the bucket. Weigh the bucket with the gallon of water and record the weight. What is the weight of a gallon of water?

Weight of water and bucket = ?
Weight of bucket = ?
Weight of water = ?

You can put 7½ gallons of water in one cubic foot of space. How much, then, will one cubic foot of water weigh? What will be the pressure on the bottom of a cube of water that measures one foot on each side?

Increasing Water Pressure

Suppose that you could put another cube of water on top of the first. You would then have a column of water that is 2 feet high, pressing on one square foot of surface at the bottom of the column. What will be the water pressure on that one square foot? If you piled 10 cubes into a similar column, what would be the water pressure on that square foot?

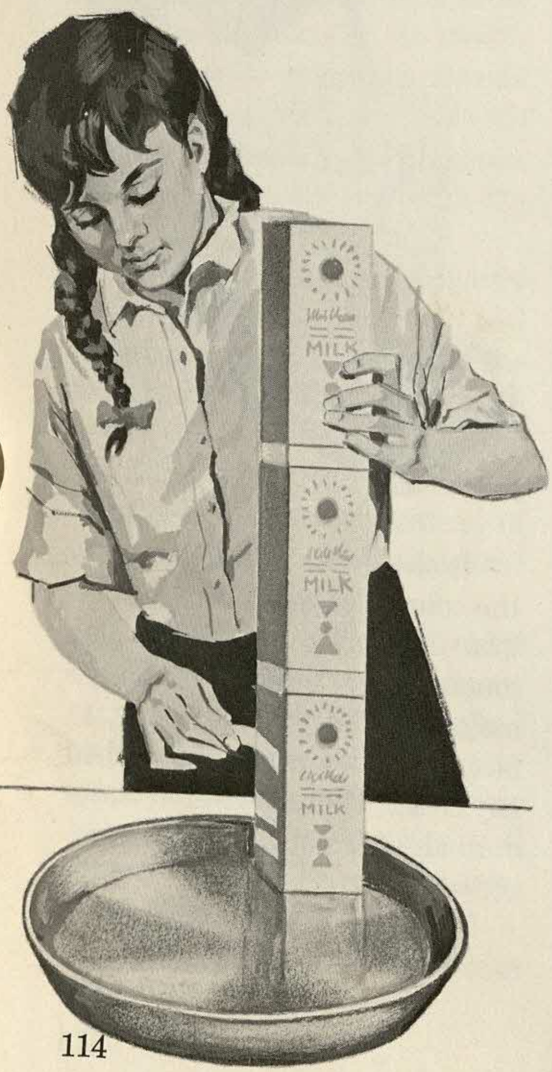
ESTIMATE Draw a square, one foot on each side. Mark off each foot into inches. Block off the square into many squares by connecting the inch marks. How many one-inch squares are there in a square foot? What would be the water pressure on a one-inch square at the bottom of the ten foot water column?

No. of 1-in. squares in 1 sq. ft. = ?
Water pressure on 1 sq. ft. = ?
Water pressure on 1 sq. in. = ?

Is the water at the bottom of the column of water compressed? The molecules of liquids are much closer together than gas molecules. They are so close, in fact, that they cannot be pushed any closer. Therefore water, under normal conditions, cannot be compressed. □□

The mass of water in one cubic foot weighs 62½ pounds, while the mass of air in one cubic foot weighs ¼ ounce at sea level. A column of water only 34 feet high exerts the same pressure as the atmosphere which extends out beyond 600 miles!

Since you live at a level more or less equal to the top of the oceans of water, what would you experience if you descended into the water?



DISCOVER You will need three milk cartons, water, a nail, tape, and a large pan. Remove the tops from the cartons. Using the nail, make three holes in the side of one carton. One hole should be near the bottom of the carton, one near the middle, and one near the top. Put tape over each hole. Hold the carton over the pan and fill the carton with water. Remove the tape from all three holes. What happens? Why? How do you explain the difference between the jets of water?

Cut the bottom out of the other cartons. Tape one carton on top of the carton you have already used. Put tape on the holes again and fill the cartons with water. Remove the tape. How do the water jets now compare with those from the single carton? Why? What did you increase when you added the other carton? Look at the sides of the bottom carton. If the sides tend to bulge, put tape around the carton. On what part of the carton should you put the most tape?

Tape the third carton into place above the other two. Repeat the activity. How do the jets of water now compare?

Use modeling clay, and plug the two top holes of the bottom carton. Place a ruler against the carton so that it extends outward from the carton, as shown in the picture. Now you will be able to measure the actual length of the jet stream. Make a table for your measurements.

Number of Cartons	*Length of Jet*
3	inches
2	inches
1	inches

Tape the bottom hole. Fill the cartons with water. Remove the tape, and check the length of the jet. Repeat the activity to check your measurement. Record your measurements. Remove one carton, and repeat the activity as before. Check and record your measurements. Remove the second carton, and repeat the activity.

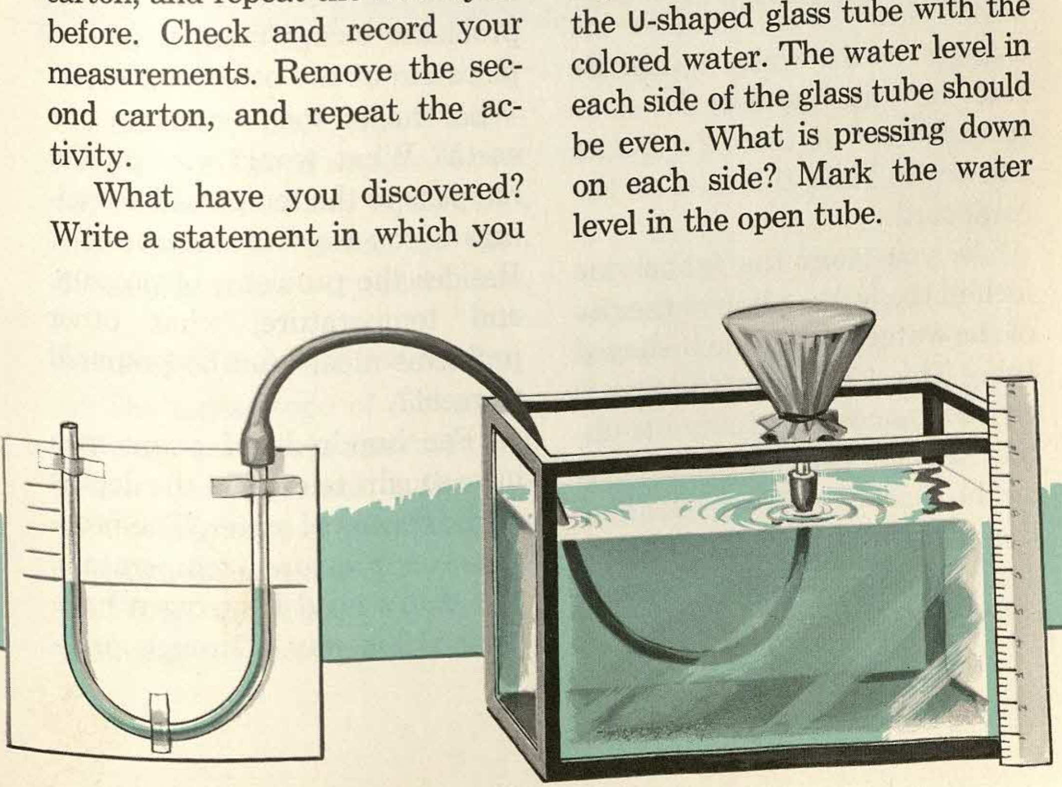
What have you discovered? Write a statement in which you explain how the height of a water column is related to the pressure the water exerts.

Testing Water Pressure

You can make your own instrument for testing water pressure.

ACTIVITY You will need a funnel, a balloon, rubber bands, a U-shaped glass tube, three feet of rubber tubing to fit the glass tube, water, food coloring, a piece of white cardboard, wire, a ruler, and a deep jar or aquarium.

Attach one end of the rubber tubing to one end of the U-shaped glass tube, and the other end of the tubing to the end of the funnel. Mix ink or food coloring with a little water. Half fill the U-shaped glass tube with the colored water. The water level in each side of the glass tube should be even. What is pressing down on each side? Mark the water level in the open tube.



Cover the end of the funnel with a piece of rubber from the balloon. Hold the rubber securely in place with rubber bands. Gently press down on the rubber. What happens? Why? What do you predict will happen if you submerge the funnel?

Fill a deep jar or aquarium with water. Slowly push the funnel into the water. Observe the water levels in the U-shaped tube. What happens? Why? The height of the water in the open tube shows the increase in the water pressure.

Hold a ruler beside the funnel and measure, in inches, how deeply the funnel is submerged. Using wire, attach the U-shaped tube to a piece of white cardboard. Now you can measure the changes in the water levels. Be sure the water level is the same in each side of the tube before you begin. Mark this level on the cardboard.

As you lower the funnel one inch in the water, observe the rise of the water level in the U-shaped tube. This kind of instrument is called a manometer (mun-OM-uh-ter). Record the new water level on the cardboard. Keep recording the changes in the water level as you lower the funnel deeper into the water.

Depth of Funnel	*Water Rise in Open Tube*
0 inches	______ inches
1 inch	______ inches
2 inches	______ inches
3 inches	______ inches
4 inches	______ inches
5 inches	______ inches

Man Explores the Ocean of Water

From your activities, what would you list as some of the problems facing man in his exploration of the oceans of water? What heats the waters on the earth? What would you predict happens to the temperature readings as you descend in the oceans? Besides the problems of pressure and temperature, what other problems must man be prepared to meet?

For hundreds of years men have sought to explore the depths of the oceans of water. The problems of pressure, temperature, and man's need for oxygen have blocked his way. Through prac-

tice and experience, expert swimmers have reached depths of over 100 feet without any equipment, but they can remain at such depths for only a very short time.

Equipment to Aid Exploration

The oldest type of diving apparatus used to aid the diver is a tube called a snorkel. A description of this type of breathing device can be found in the writing of Pliny the Elder, a Roman author of the first century A.D.

A snorkel, a face mask, and flippers allow man to breathe, see, and move easily under water. Man is able to see the bottom of shores which, without such equipment, he could only feel with his hands or feet. Even with this equipment, however, man cannot search to any great depth. He cannot explore much deeper than his own height.

Until 1819, man had less success in descending in the ocean of water than in ascending in the ocean of air. In that year, an Englishman, Augustus Siebe, invented a diving helmet. Diving helmets are equipped with glass ports which allow the diver to see. An air hose and a life line are attached to the back of the helmet; air is forced into the helmet through the air hose so that the diver can breathe. The life line contains a telephone cable which connects the diver to the boat on the surface.

Deep-sea divers, wearing airtight, rubberized canvas suits, helmets which screw onto a breastplate, lead-soled shoes, and belts with lead weights, have reached depths of 600 feet. At that depth the water pressure is about 19 tons on one square foot! And yet, 600 feet is only about a tenth of a mile below the surface. One of the first balloon flights reached that height in the atmosphere within the first year of balloon flights. Why is exploring the ocean so much more difficult than exploring the atmosphere?

The invention of the aqualung in 1933 introduced a new and simpler form of water exploration. Today, diving with these lungs is known as scuba-diving.

Why do many skin-divers wear a protective suit of thin rubber? What are some other hazards that divers face besides pressure, temperature, and the lack of oxygen? What causes winds in the atmosphere? Water is unevenly heated, too. What movements in the water are like the movements of the winds in the atmosphere?

Divers are now exploring the oceans more than ever before. They are searching for oil, minerals, and the remains of wrecked vessels. They are also observing the habits of sea life. Many people skin-dive as a hobby. Their experiences are adding to man's knowledge of the oceans. These divers, like the early balloon pioneers, always face the unexpected on their trips into the seas.

How Objects Float

More than a thousand years before Pliny the Elder wrote about exploring under water, man was already exploring the surface of the seas. Perhaps man's first trip in deep water was on a floating log. Later he may have cut out the log and used it as a canoe. The Egyptians built large sailboats which were equipped with long oars to move the boats in calm weather.

COMPARE Collect several objects, including paper clips, marbles, bath stoppers, corks, balls, bottle tops, spoons, cans, and waxed cartons. Sort these objects into three different piles according to their weight. By tossing each one up and down in your hand, you should be able to tell if it is light, medium, or heavy. Test each group, observing what happens to each object when you drop it into the water. Why do some objects float, while others sink? Make a chart and keep a record of which objects float and which sink.

Now sort out the objects according to size, separating them into three piles of small, medium, and large objects. Test each group, and observe what happens when you drop each object into the water. Does size change an object's capacity to float?

Drop a small tin can into water. Turn it around in different positions. What do you observe? Remove the can from the water, and jump up and down on it until it is completely flattened. Now drop the tin can into the water. What happens? Has its weight changed? What has changed? What two facts about an object might determine whether it floats or sinks?

DISCOVER Take some heavy aluminum foil and a pan of water. Crush the foil into a tight ball, and drop it into the water. What happens? What force is acting on the ball of foil?

Carefully flatten out the foil, and shape it into a small boat. Hold it over the water, and then let it drop. What keeps the boat afloat? The water pushed aside is called displaced water.

Push the palm of your hand down on the water. The upward push of water against your hand is called buoyancy (BOY-un-see). The buoyancy of water pushes up on an object; gravity pulls down on an object.

When an object sinks, which force is greater? When it floats, which force is greater?

ACTIVITY Get a toy wooden block, a can of water, a large dishpan, and a spring balance. Place the can in the dishpan. Fill the can to the very top with water. Wipe up any water that spills over into the dishpan. Carefully place the toy block in the water. What happens? The water which the block has pushed over the sides of the can is called displaced water. Weigh the displaced water. Weigh the block. Compare the two weights. What do you conclude? □□

To float, an object must displace its own weight. A Greek scientist, Archimedes (287-212 B.C.), discovered this fact over two thousand years ago. A balloon floats in the air because the balloon displaces an amount of air which equals its own weight. An

80,000 ton ship floats in water because it is so built that it displaces 80,000 tons of water.

OBSERVE You will need a No. 3 tin can, sand, an aquarium of water, and a plastic ruler. Tape the ruler to the outside of the aquarium. Fill the aquarium to within two inches of the top. Put enough sand in the bottom of the can so that it floats upright. Note the water level. How much of the can is submerged? Increase the amount of sand inside the can. What happens to the water level? How far is the can submerged?

Why do loaded ships float low in the water? What weight of water must a ship displace?

Ocean Water

DISCOVER You will need a glass of water, a fresh egg, and salt. Will the egg float in water? Try it. Now dissolve as much salt as you can in the water. Stir the water carefully. Add more salt and stir. What happens to the egg now? Why?

Ocean water and sea water are both salty. Where do you think a boat will float higher, in salt water or fresh water?

DESCRIBE Fill a pie plate with water, and place it on a flat surface. Wait until the water surface is smooth. Without touching the pan, put your mouth at water level and blow over the surface of the water. Time your breathing so you blow at equal intervals. What happens?

Let the water settle. Blow again in very strong puffs. What happens? What causes waves in large bodies of water? ☐☐

Just as there are air currents, there are also water currents. What causes water currents? What effect might temperatures have on water currents?

ACTIVITY You will need two milk bottles, water, red ink, and a pan. Fill one bottle with hot water, add enough red ink to color the water, and set the bottle in the pan. Fill the other bottle with very cold water. Cover this bottle with a thin piece of cardboard. Keeping your hand on the cardboard, turn the bottle of cold water upside down over the bottle of hot water. Be sure the tops are in line. Carefully remove the cardboard and observe what happens. Why? Is hot water more dense or less dense than cold water? Does it have the same density? Where would the water in the oceans be cold? Hot?

COMPARE Pour some very hot water into a sink. Let the water be as hot as you can stand to touch. Then slowly add cold water. Where do you find the cold water in the sink?

Pour some very cold water into the sink. Then slowly add very hot water. What happens? □□

Different areas of water in our oceans and seas differ in temperature and saltiness. These differences cause variations in the density of the water. Dense water tends to sink toward the bottom of the ocean or sea, while less dense water tends to rise. Hence, there is a pattern of ocean currents very similar to the pattern of wind currents.

One of the problems investigated by scientists during the International Geophysical Year was whether or not water moves in definite cycles. Weighted lines with instruments attached were dropped into the ocean. These instruments checked temperatures, salt content, and the direction of currents. So much new information was discovered during the eighteen months of investigation, that a permanent research laboratory was established at Woods Hole Oceanographic (o-shuh-nuh-GRAF-ik) Institute on Cape Cod.

At the Institute, ocean currents are reproduced in big, circular tanks that can be turned to imitate the rotation of the earth. Winds are blown across the surface of the water. When the investigators think they have discovered a new fact about the sea, they then turn to the actual sea to test their idea.

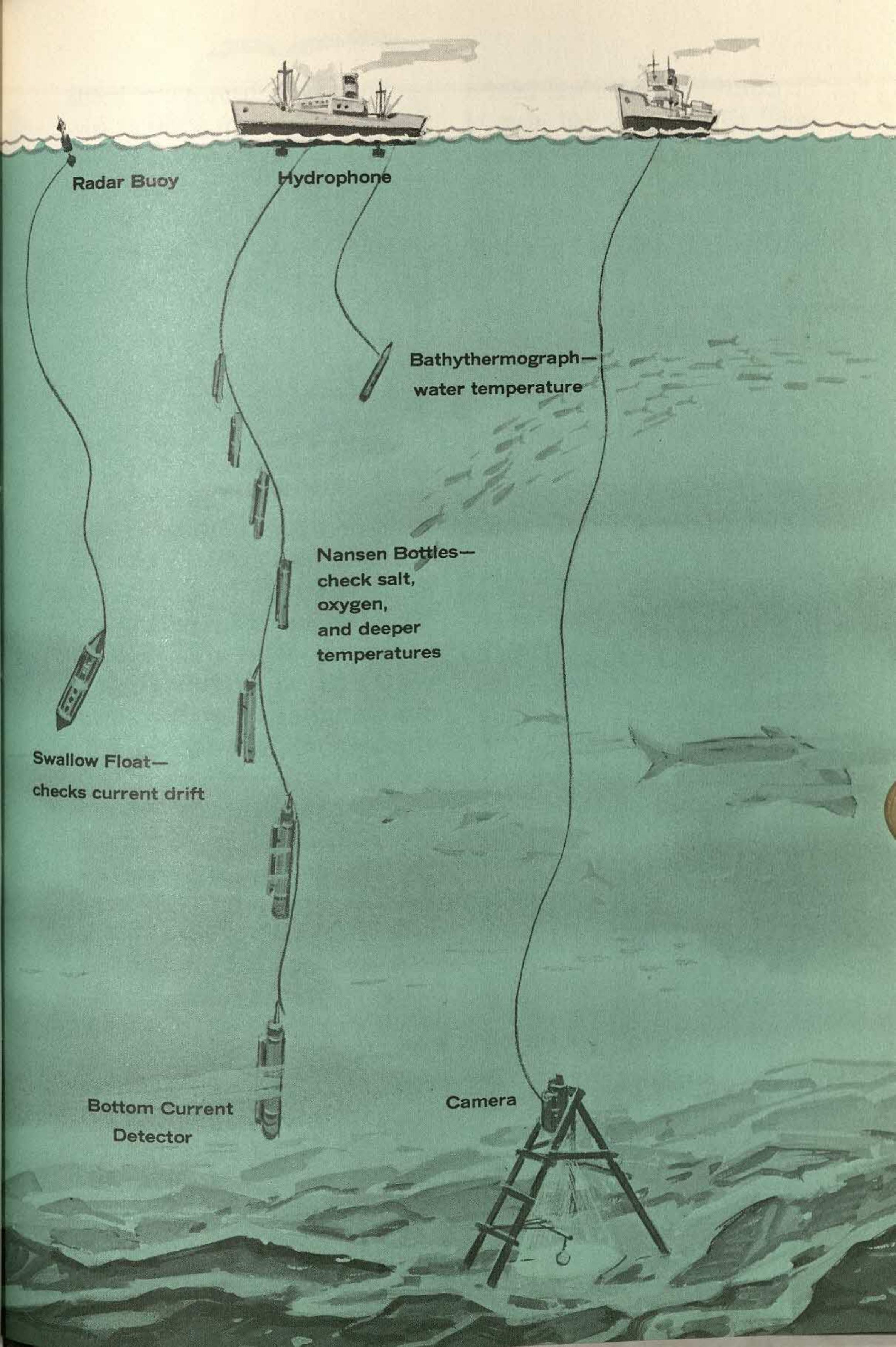
The ocean of water is just beginning to be explored in depth. The lowest depths of the ocean are still almost completely unknown to man.

Man Travels Under Water

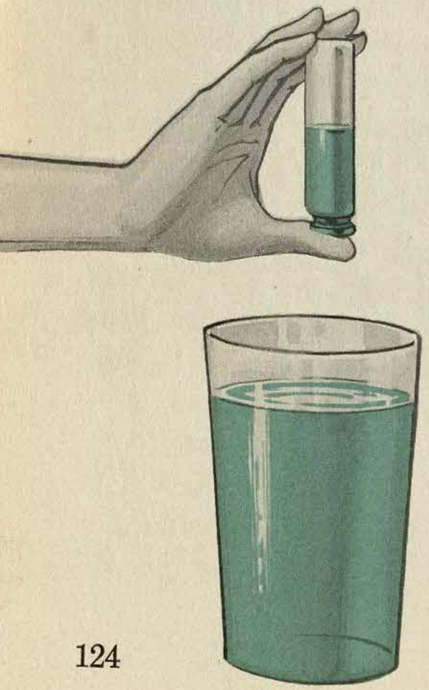
Man dreamed of traveling under the water many hundreds of years ago. In 1620, a Dutch scientist, Cornelius van Drebbel, covered the top of a row boat with leather and demonstrated his submarine. For a short time, he remained submerged 12 to 15 feet below the surface of the Thames.

In 1864, the Hunley, a Confederate submarine, rammed a Federal warship and sank it. The Hunley was a hand-powered submarine. In 1890, John P. Holland, an American, built the first successful naval submarine. It was 53 feet long and displaced 75 tons of water. Compare this size with the size of submarines today.

Submarines are used mainly for military purposes, but from their travels under the seas much knowledge of water currents and temperatures has been gathered.


Radar Buoy
Hydrophone
Bathythermograph—
water temperature
Nansen Bottles—
check salt,
oxygen,
and deeper
temperatures
Swallow Float—
checks current drift
Bottom Current
Detector
Camera

COMPARE You will need a small pill bottle, a tall glass of water, and a piece of rubber from a balloon. Fill the small bottle about half full of water. Pour water into the tall glass to within 1½ inches from the top. Place your finger over the mouth of the small bottle, and, holding it upside down, put it in the glass of water. The bottle should just barely float so that its bottom is slightly above the surface of the water. If the bottle does not float in this way, the amount of water in the bottle must be changed. If it sinks below the water level, should you add more water or decrease the amount of water? If it bobs above the water level, what must you do?



When you have your bottle floating in the right position, cover the top of the glass with the piece of rubber balloon. Be sure to fasten the rubber securely in place. Now press down on the rubber covering. What happens to the bottle inside the glass? Increase your pressure. What happens? Why? Release your pressure. What happens? Why?

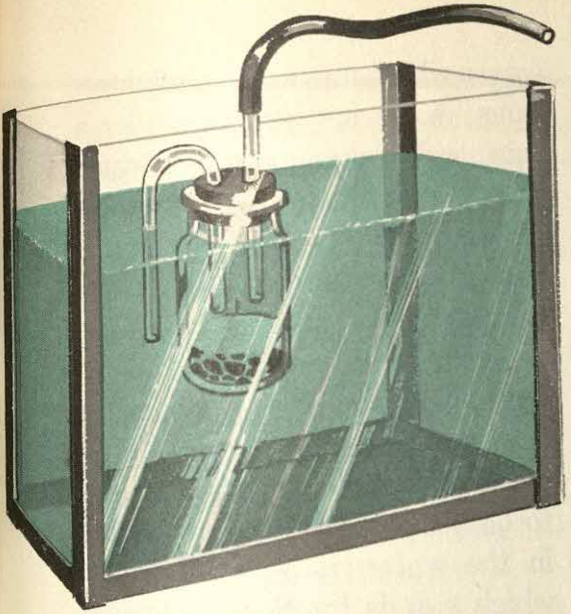
When you press down on the rubber, the air above the water is compressed. The compressed air pushes down on the water, forcing it into the bottle. In this way, the air in the bottle is compressed. Why does the bottle sink?

When you release the pressure, some of the water in the bottle is pushed out again by the expansion of the air in the bottle. Why does the bottle rise?

By controlling the pressure you use to push down on the rubber top. you can completely control the upward and downward movement of the little bottle. You can even keep the little bottle suspended midway in the water. Try it. ☐☐

Submarines work on much the same principle. You can make your own submarine.

DESCRIBE Take a wide-mouth bottle, paraffin, pebbles, a two-hole stopper, a U-shaped



glass tube, a piece of rubber tubing, and a straight glass tube. You will also need an aquarium of water. Cover the bottom of the bottle with pebbles. Then pour melted paraffin over the pebbles to keep them in place. Put the U-shaped glass tube through one hole of the stopper, and the straight glass tube through the other. Attach the rubber tubing to the straight tube. Insert the stopper in the bottle, as shown in the picture. The bottle should now float in an upright position.

Suck air out of the rubber tube. Why does water enter the bottle? What happens to the bottle? Blow air into the tube. What happens to the bottle? Why?

How does a submarine rise to the surface of water? How does it submerge?

Exploring Ocean Depths

How is the safety depth of a ship determined? What would happen if a large ship entered shallow waters? Is the depth of the ocean the same in all parts? How can the depth of the ocean be measured? Such questions are of major importance to the captains of ships, since certain depths are necessary for safe sailing.

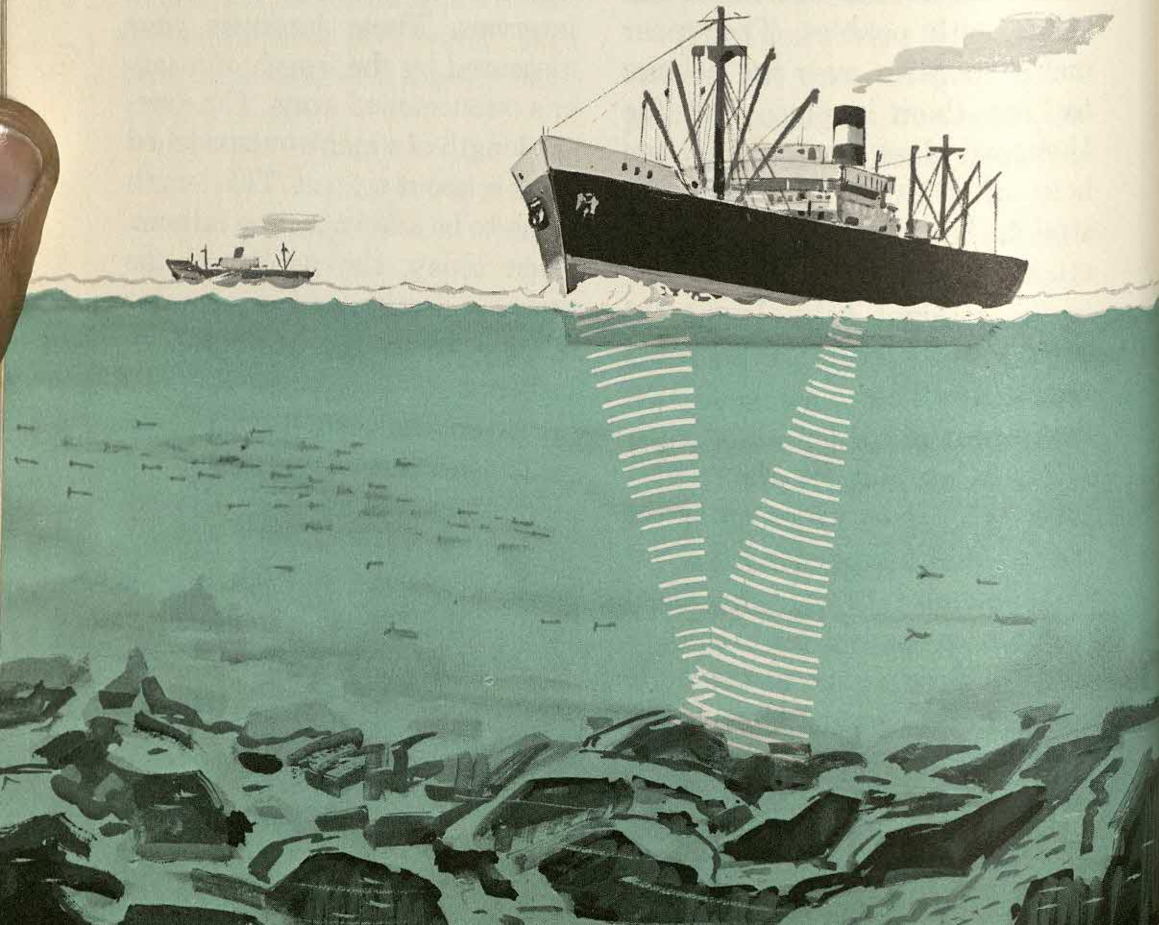
Before modern instruments were invented for measuring the depths of the sea, sailors had to rely on more primitive methods. They would take a long rope, and tie knots in the rope at regular intervals. These intervals were measured by the length of a sailor's outstretched arms. The average length of a man's outstretched arms is about six feet. This length came to be known as the fathom. Even today, the depths of the ocean and other bodies of water on the earth are measured in fathoms.

After the invention of the radio and the development of electronics, new methods of measuring the ocean depths became possible. Sound, for example, is now used for such measurements. The following activity will help you to understand how sound can be used to measure water depth.

OBSERVE Fill a basin with water. Now fill a medicine dropper with water, and release the water, a drop at a time, into the basin. What happens? How do the ripples move? Watch the ripples as they reach the side of the basin. What happens?

Release three drops at equal time intervals, counting "1-alligator," between each drop. What happens to the ripples after they have struck the sides of the basin? You have seen the same thing happen if you have ever watched waves raised by a motor boat, hit the side of a dock. □□

Sound, like water, travels in waves which move out in all directions. A device located under a ship sends out sound waves which travel downward. When these waves hit the bottom of the sea, they bounce back. By measuring the length of time it takes the sound to complete its journey to the bottom and back, the depth of the sea can be accurately determined. When this method is used to detect the presence of objects in the water, it is called sonar, which stands for *So*und *Na*vigation and *R*anging.

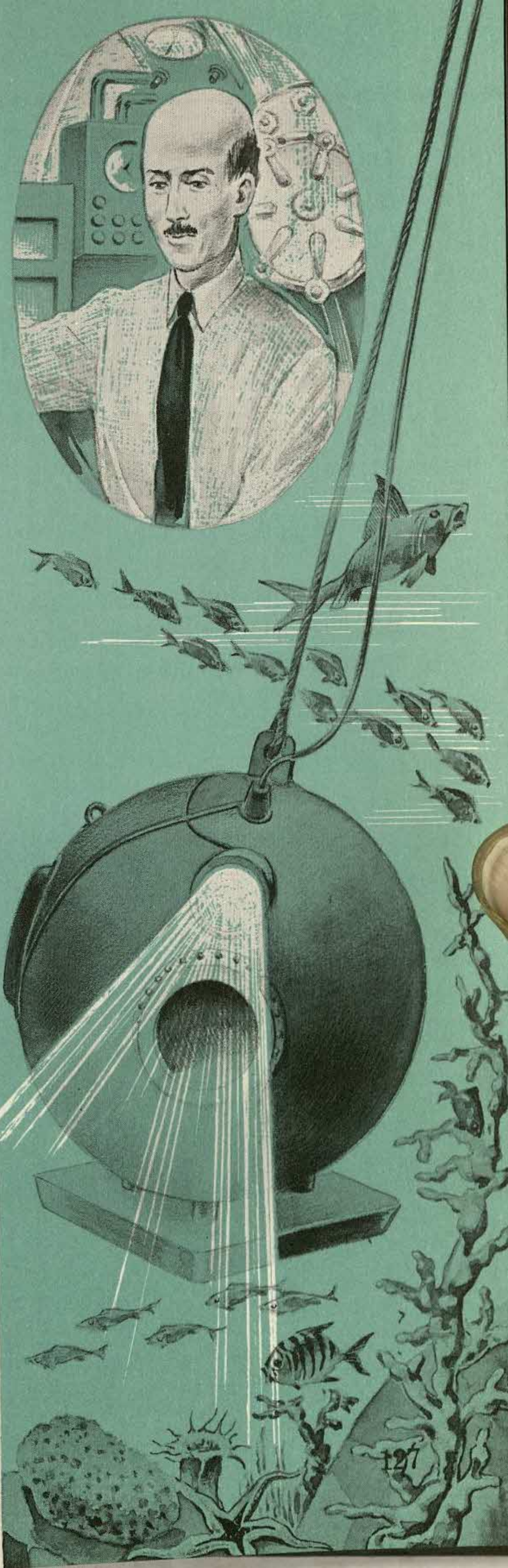


Fishing boats are equipped with sonar to locate schools of fish. Sonar is used on military vessels to detect submarines and mines. Sonar also helps scientists chart the ocean bottom. What has been discovered about the ocean floor?

Try to picture an underwater continent, rich with valleys, canyons, plains, and mountains. The tallest mountains and deepest valleys on earth are buried far below the surface of the sea.

One of the first men to explore this "lost" continent beneath the seas was William Beebe (1877-1962), an American scientist. In 1930, he built a heavy steel ball, called a bathysphere (BATH-iss-feer), in which he was lowered thousands of feet into the sea. In the bathysphere, Beebe had built observation windows. These windows were made of special transparent material strong enough to withstand the immense water pressure. Beebe descended to the depth of half a mile. At that depth the temperature is about 22°F, and the water pressure about half a ton per square inch!

Beebe made many trips into the sea, photographing the deep-sea life all around him. Beebe's startling photographs showed many kinds of strange, unfamiliar forms of plant and fish life.

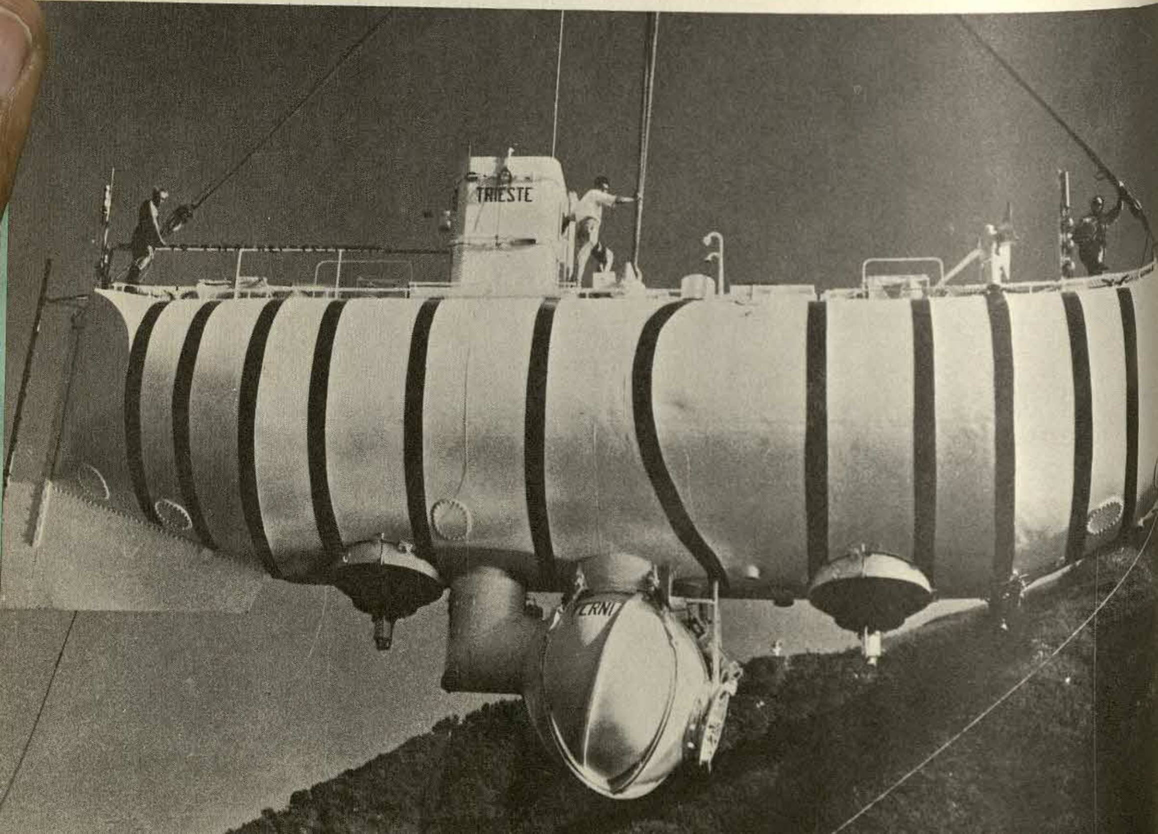


In 1960, Jacques Piccard, Auguste Piccard's son, and Lt. Donald Walsh, an American, descended 35,800 feet in a diving craft called a bathyscaphe (BATH-ih-skaf). Piccard and Walsh reached the bottom of a huge, deep crack in the Pacific Ocean known as Marianas Trench. At this depth, the pressure is about six tons on a square inch! Can you imagine what forms of surprising, unknown plant and fish life they observed?

From the discoveries of these men and others like them began a new science, devoted to the study of our vast and still mysterious oceans. This new science is called oceanography.

A New Frontier: Space

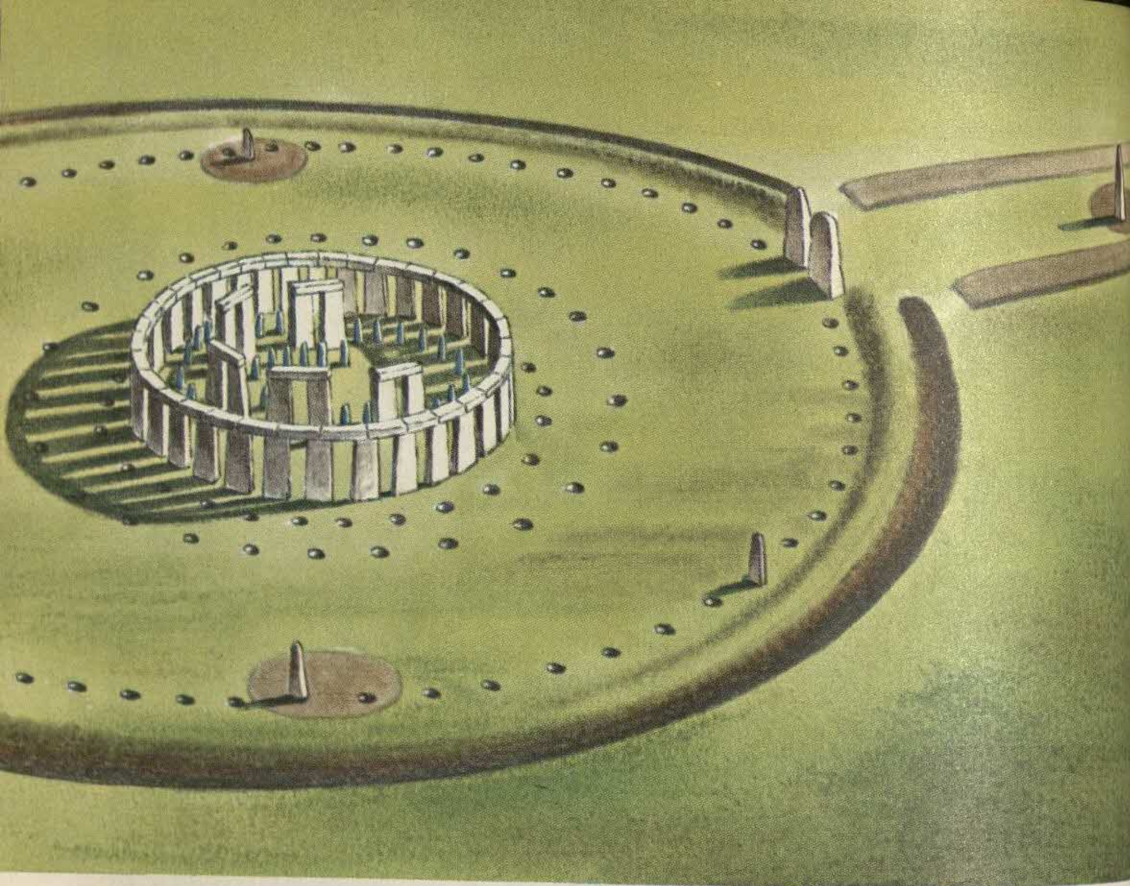
Man has ascended hundreds of miles in the atmosphere, conquering the intense cold, the lack of air pressure and oxygen, and the tremendous pull of the earth. He has descended to the depths of the oceans, conquering immense pressure, cold, and lack of air. In each conquest man has discovered more wonders, more mysteries, and more unanswered questions than he had ever imagined. The work of the early explorers in the oceans of air and water has led to the then unforeseen achievements of today's oceanauts and astronauts. What frontiers might yet be discovered!



Galaxy NGC 5128 is an unusual type and a source of radio noise.

Today man is just beginning to venture into the space frontier. Man is using optical telescopes, radio telescopes, rockets, and satellites as tools to help him gather as much information as he can. But man has been observing and studying the objects in space for many centuries, long before these tools were invented.

One of the most important "tools" that early man used was his eyes. By looking at the sky day after day and by keeping track of his observations, man of long ago learned many things.



Scientists' idea of what Stonehenge looked like

Motions in the Sky

Early man discovered that the sun, moon, and stars seemed to change their position in the sky. From their observations, ancient peoples were able to make accurate calendars. These early calendars helped them to know when to plant seeds and when to harvest their crops. Many scientists believe that a group of large stones at Stonehenge, England were used about 2,000 B.C. to observe and predict the movements of the sun and moon.

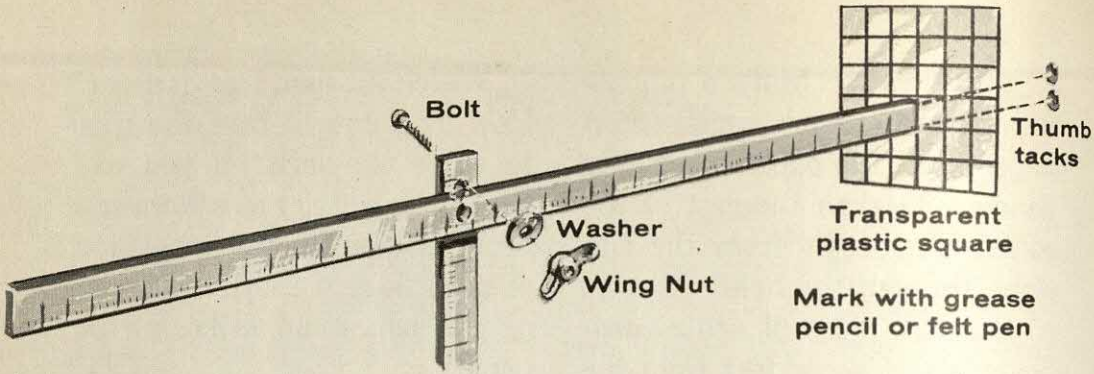
On the longest day of the year, the sun rises over the Heel Stone.

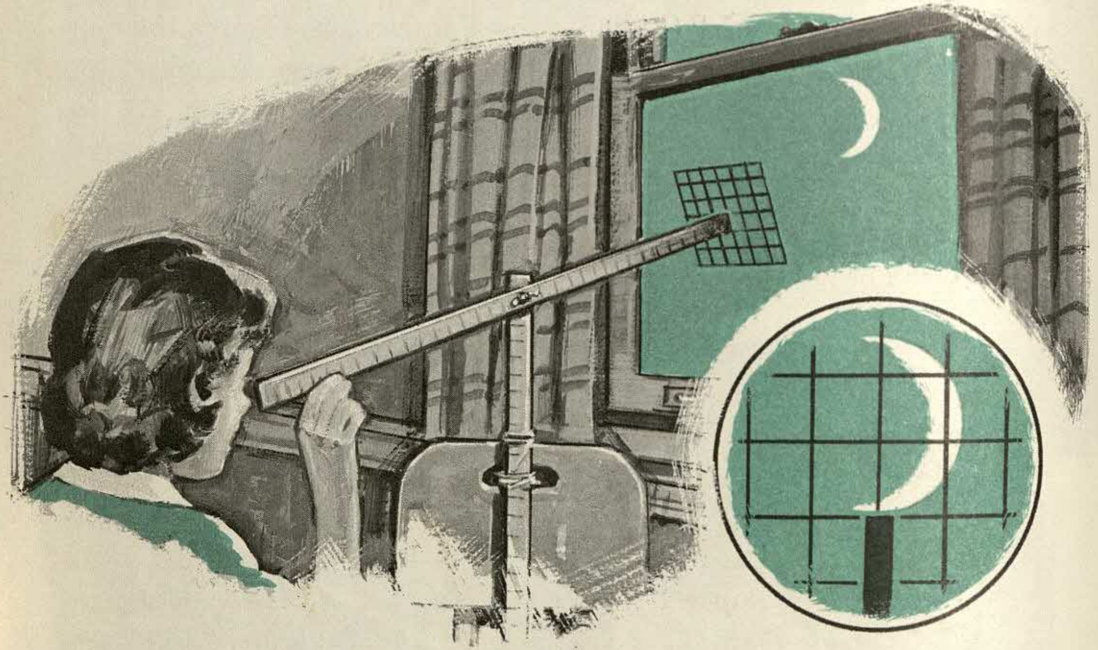
CONSTRUCT Make a pinhole in a piece of black construction paper. Tape the paper on a sunny window. Darken the rest of the room. Does light from the sun shine through the hole?

Stand a piece of white cardboard about three feet from the window. You will see a small bright spot on the cardboard. This spot is an image of the sun. Mark the location of the spot with a pencil.

Watch the spot. Does it move? How long does it take the spot to move one inch? If you had begun this activity at sunrise and continued until sunset, what kind of path do you think the image of the sun would make on the paper? ☐☐

You can also observe the motions of the moon and stars, but since these objects are not as bright as the sun, you can observe their movements directly.


Bolt
Washer
Wing Nut
Thumb tacks
Transparent plastic square
Mark with grease pencil or felt pen



OBSERVE Drill a ¼-inch hole near the end of a yardstick. Label this yardstick A. Drill a hole in the center of another yardstick. Label this stick B. Attach the sticks together with a bolt and wing nut. Use a grease pencil or a felt marking pen to make one-inch squares on a plastic sheet. Attach the sheet to one end of stick B as shown. Attach stick A to a wooden chair.

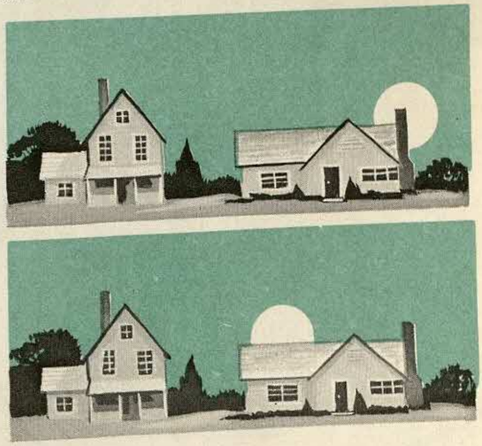
Place this instrument in a room that has a window facing the moon. Sight along the upper edge of stick B. Adjust the chair and stick B so that the moon appears to be sitting right on the end of stick B. Make sure your eye is close to the stick as you sight the moon along it. Once your instrument is adjusted, do not move it. Wait 5 minutes and look along the stick again. Has the moon moved? How far? Wait 5 minutes more then look again. Where is the moon now?

Look for a bright star near the moon. Mark its location on the plastic sheet. Does the star move across the sky too? How does its motion compare to the moon's motion? Is it slower? ☐☐

From observations of this kind, ancient people came to believe that the sky was like a giant bowl with the earth at the center. They watched the movement of the sun, moon and stars and thought the sky turned from east to west once each day. From your observations, does this seem reasonable to you?

Ancient people also noticed that an orderly change took place in the sky from day to day and from month to month. The sun rose above the horizon from a slightly different spot each day. As time progressed day by day, the sun would move a little farther north. Then, it would reverse this motion and begin to rise a little farther south each day. This regular pattern occurred over and over. Ancient people called one complete pattern a "year."

DISCOVER Observe the position of the sun early in the morning. Draw an imaginary line straight down from the sun to the horizon. Make a drawing of the sun's position. Also make a note of where you are standing. Return to this spot for several days in a row. Does the sun rise above the same spot each day? Note the position of the sun a week later, and a month later. How long do you think you would have to wait in order to observe the sun rising over the spot you marked on the first day?



Shadow Clocks

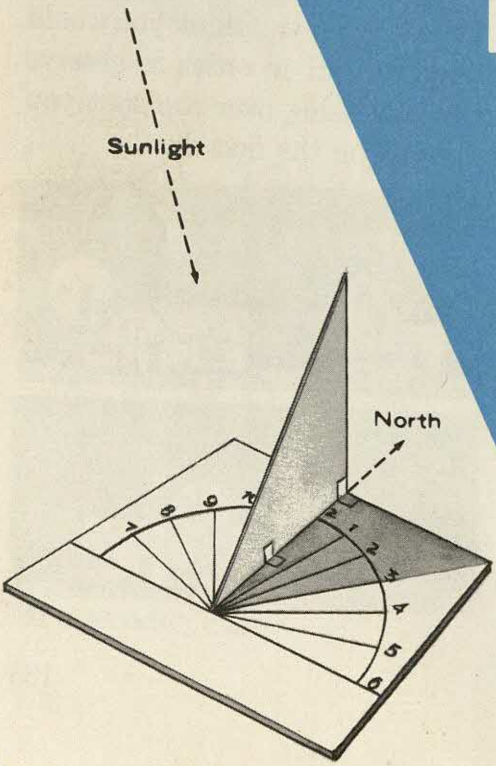
Shadows were used by ancient people to help them tell the time of day. First, upright sticks were used. On a sunny day the shadow cast by a stick could be seen to change. Later, a more accurate device, called a sundial, was used.

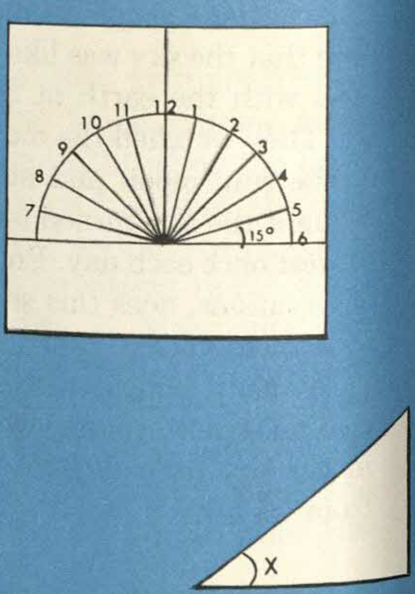
A sundial is made up of two main parts, a gnomon (NOH-mahn) and a dial plate. The triangular piece which is placed upright on the dial plate is called the gnomon. The gnomon casts a shadow during the daylight hours. This instrument was the main timekeeper used in ancient times. You can easily make a model sundial which will tell time.

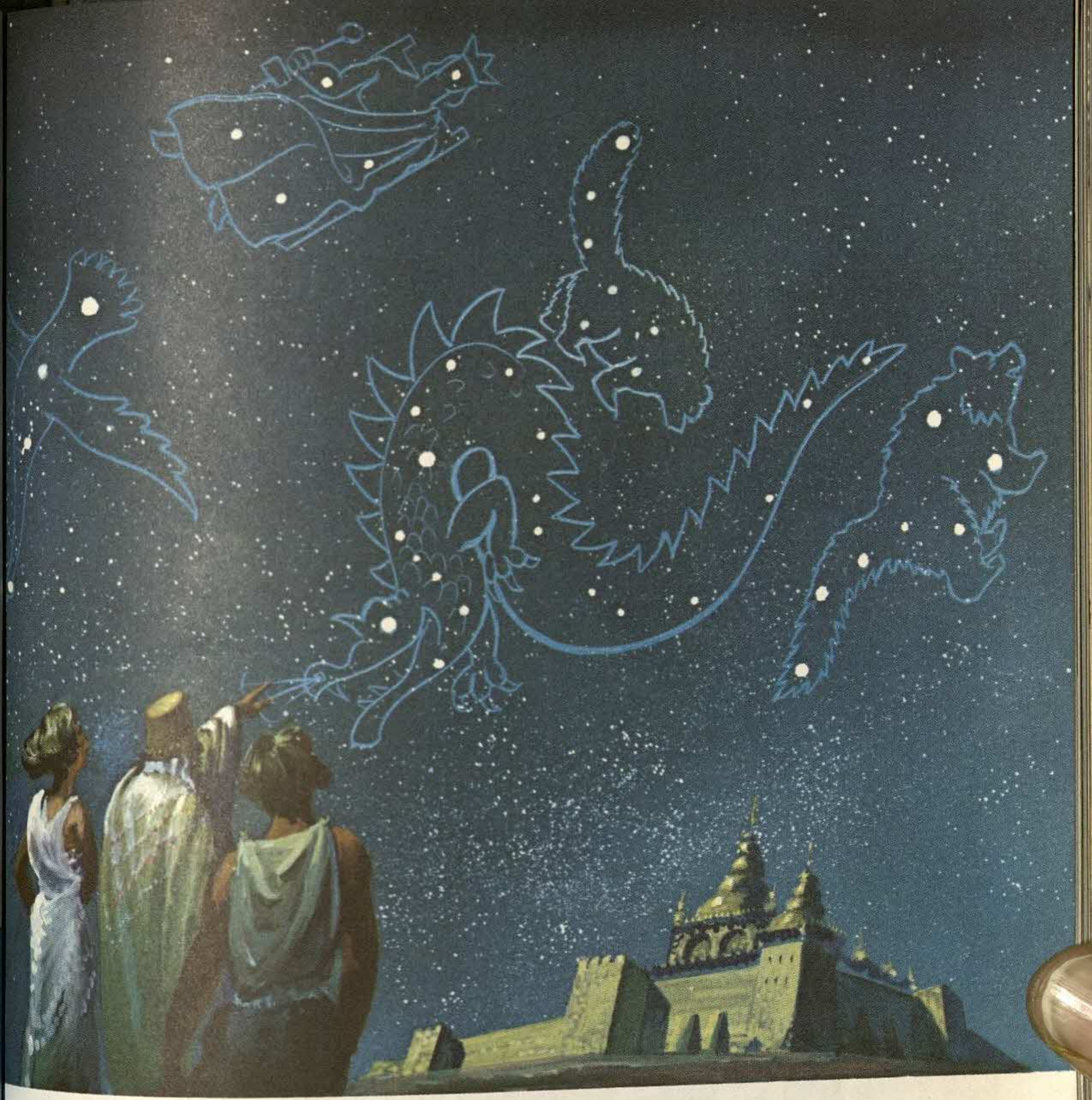
CONSTRUCT Mark a 10-inch square of cardboard as shown. The angle between each pair of hour lines should be 15°.

In order to make the gnomon accurately, you must know how many degrees north of the equator your school is located. That is, the angle X must be the same number of degrees as the latitude of your school. You can find this latitude on a map or in an almanac. Draw the correct angle using a protractor. Attach the gnomon to the dial plate as shown, using tape or glue.

Place your sundial outside or on a sunny window sill. Make sure the gnomon is pointing directly north. Why was it necessary to make the angle between the hour lines 15°?







Constellations

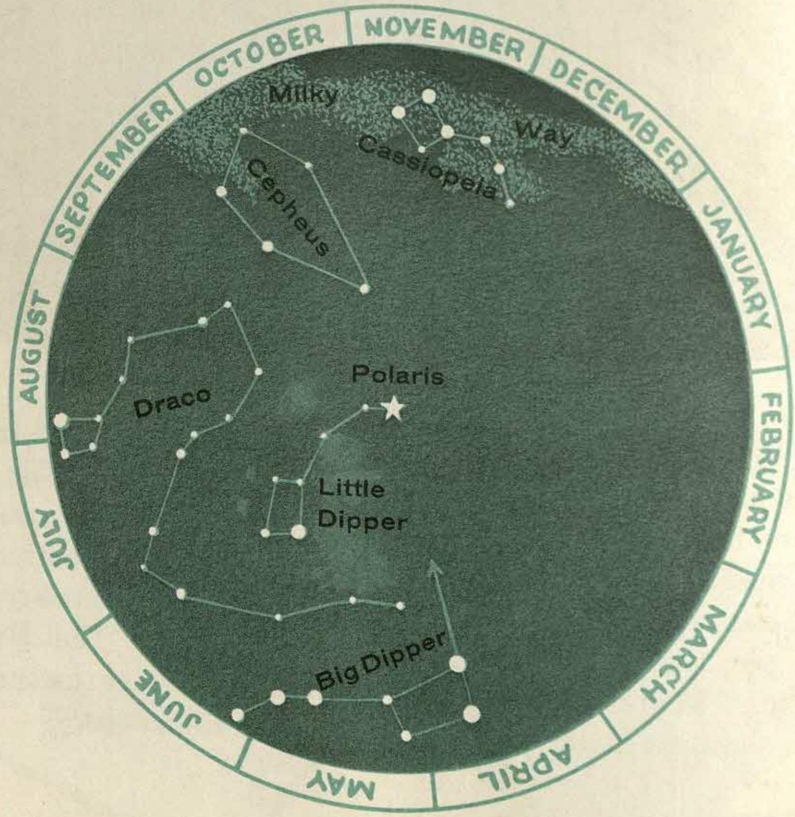
Long ago people noticed that the stars followed a path from east to west across the night sky. They observed that each star kept its position in relation to the other stars. Many stars seemed to form patterns in the sky. To some observers the patterns suggested animals like "The Great Bear" or birds like Cygnus, "The Swan." Some star patterns reminded others of legendary heroes such as Orion, "The Hunter." Today these star patterns are called constellations.

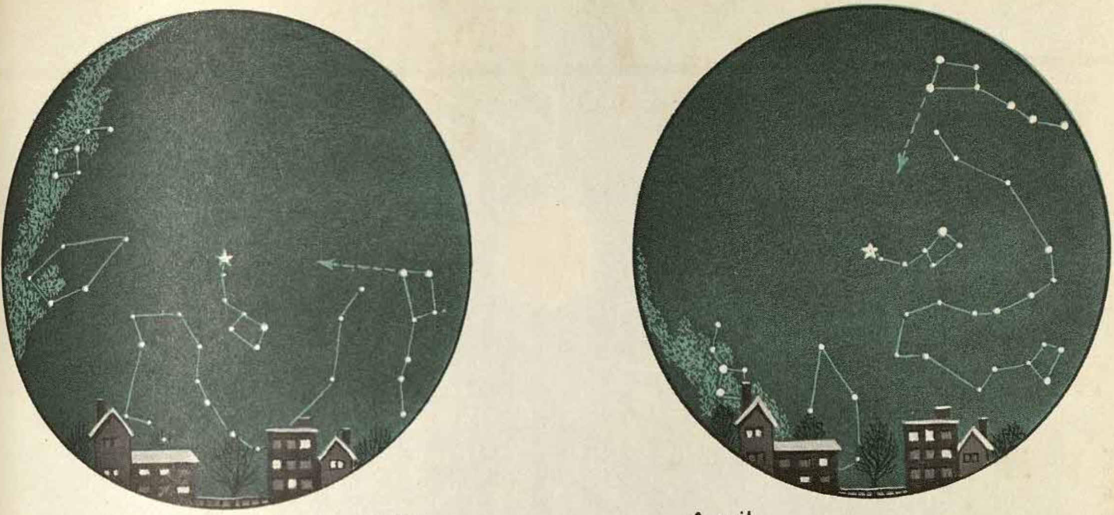
EXPLORE Choose a clear, starlit evening near the time of a full moon for this activity. You can find out when a full moon will occur by consulting a calendar. Sometime between 7:00 P.M. and 9:00 P.M., face the northern part of the sky. Look for groups of bright stars. Use the star chart.

Find the group of stars called "The Big Dipper." There are seven stars in this group. Three stars are in the handle and four are in the bowl.

The two stars that form the front of the bowl are called pointer stars. Notice how an imaginary line through these two stars points to Polaris, "The North Star." If you continue this imaginary line across the sky you will see a group of five stars arranged like a box with a triangle on top. This group of stars is called Cepheus (SEE-fee-us). Of what does Cepheus remind you? A house? A church? Make up a drawing for this star pattern.

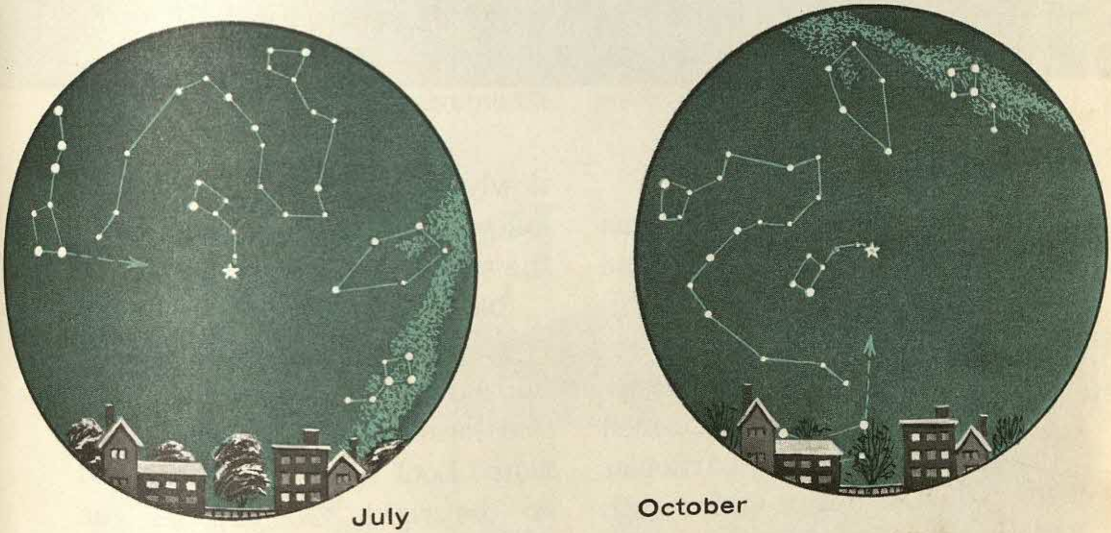
Can you find Draco (DRAY-ko)? Does Draco remind you of anything in particular? Discuss your observations with other members of your class. Do you agree on what you saw? Did the stars suggest different patterns to some of your classmates? □□





January

April



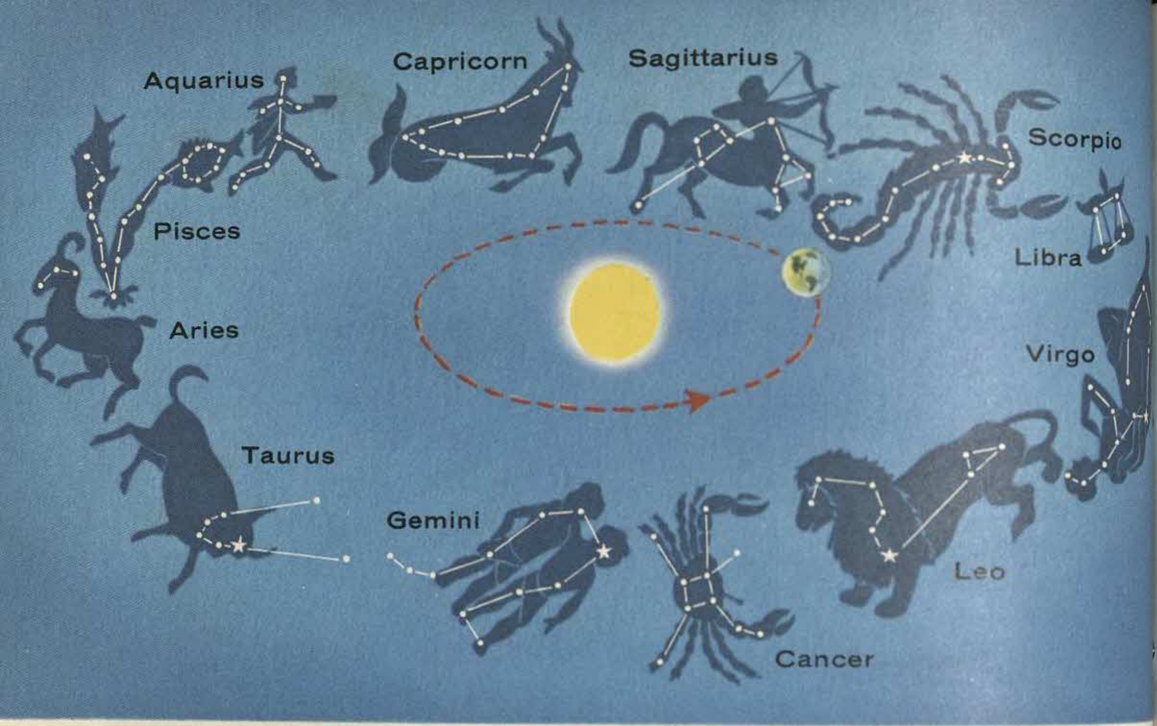
July

October

The stars around Polaris seem to turn a full circle in a year.

The five star groups shown here are called the North Circumpolar Constellations. Although these groups of stars change their position in the sky from month to month, they never set. That is, they can be seen above the horizon on any clear night of the year.

LOCATE To locate the positions of these stars for any month, hold the chart so that the current month is at the top. Face north. The constellations will then appear in the same position on the chart as they do in the northern sky at about 9:00 P.M.



The Zodiac

People of early civilizations long ago noticed that not all the star groups appeared each night. Some constellations only appeared during certain seasons. They noticed that the sun seemed to rise and set with a particular group of stars during each month of the year. The twelve constellations which make up this group are called the zodiac (ZOH-dee-ak) constellations. The word zodiac is a Greek term meaning "circle of animals."

The zodiac constellations were first named over 2,000 years ago. Each group of stars rises in the west above the setting sun for about a month. Each group is slowly replaced by the one that follows until, twelve months later, the same group returns.

DISCOVER Observe the group of stars that appears above the horizon shortly after sunset. Can you locate the zodiac constellations? Look above this group and to the right. Do you see the zodiac constellation that was above the horizon during the previous month? □□

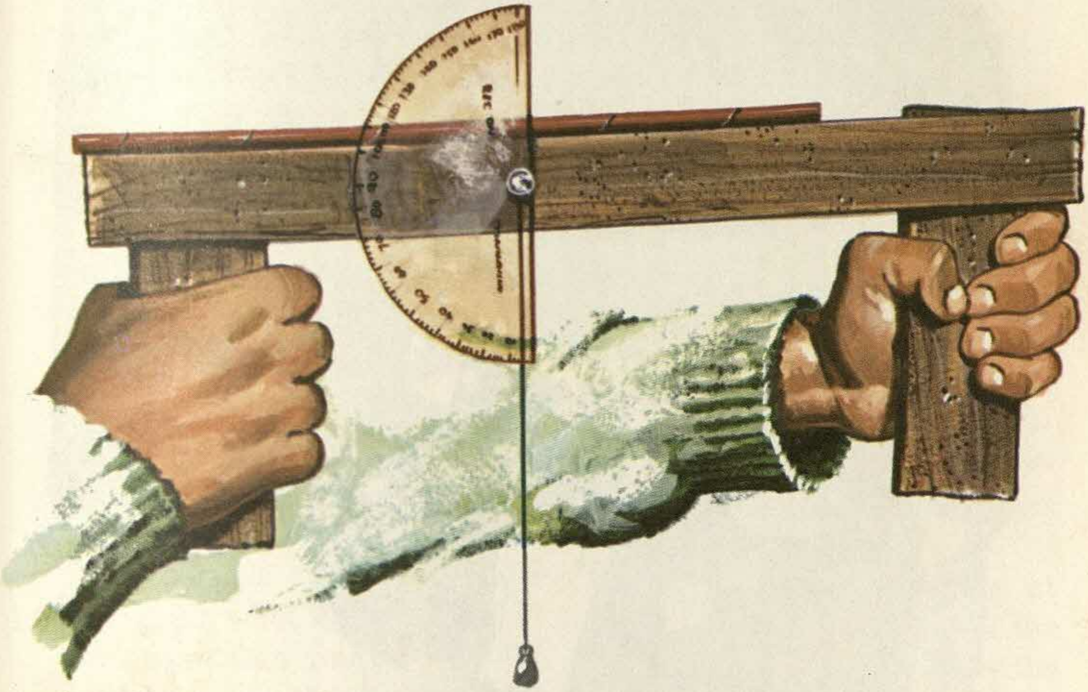
Ancient people did not understand why stars appeared to form groups. They did not know what caused constellations to change their positions in the sky from month to month. But they did understand that the motion of the sun, moon, and stars was very precise. They made careful maps of the constellations and learned to predict movements in the sky with great accuracy.

Locating Positions

By locating the North Star and other stars in the night sky, early navigators were able to tell where they were while at sea. This helped them to travel to distant places and back without getting lost. By the time of Columbus, an instrument called a sextant was used by navigators to make accurate measurements of how high above the horizon certain stars appeared in the sky.

ACTIVITY You can make a simple sextant that will be useful in later activities. Attach two blocks of wood to a one-foot stick or ruler. The blocks can be used as handles to hold the device steady. Mount a plastic straw to the top of the stick. Fasten a protractor to the side of the stick as shown in the picture.

Attach a thread with a small weight at one end to the center base of the protractor at its index point. Make sure the thread hangs



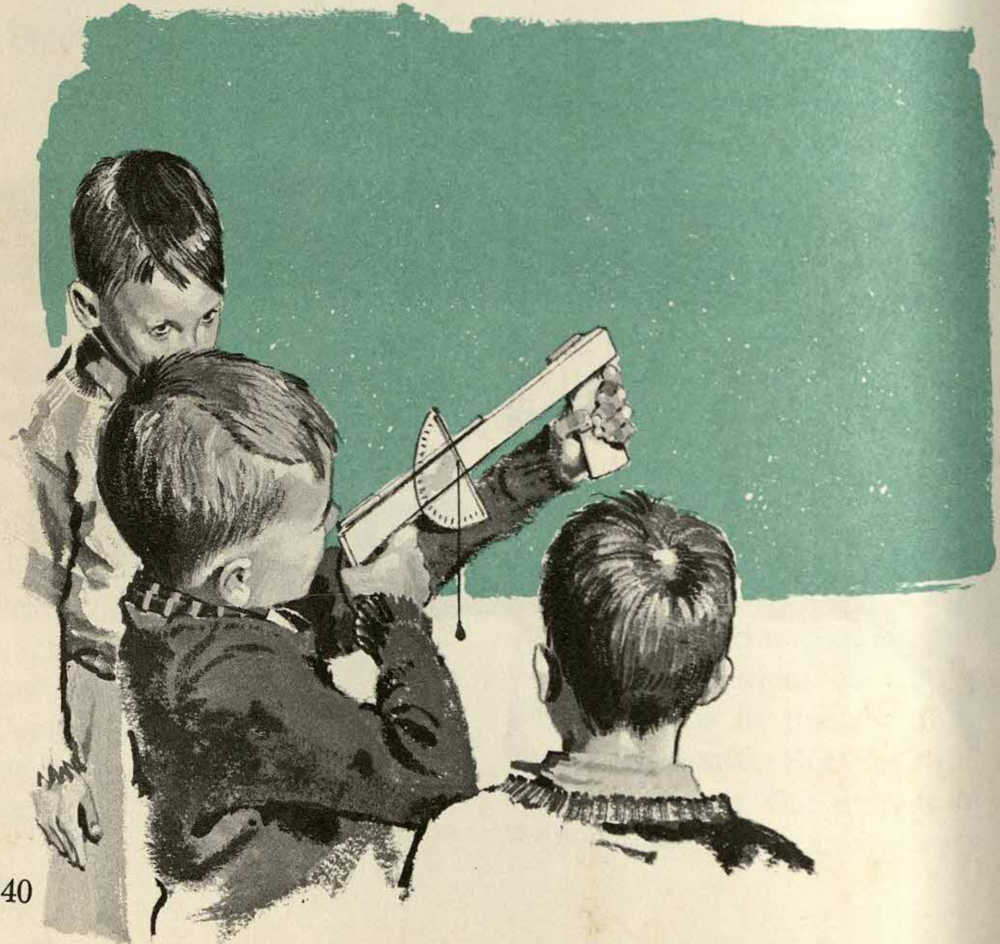
freely and parallel to the protractor's base at the 0° mark. Use the picture to help you construct the sextant. Now when you hold your sextant parallel with the ground, as shown, the thread will cross the protractor at 0°.

As you tilt your sextant slightly upward toward the sky, observe the weighted thread. Does it change its direction? Does it cross the protractor at a different place? Does the tilted protractor make an angle with the ground? How can you tell what size the angle is?

If the weighted thread crosses the protractor at 10°, how far upward have you tilted your sextant? What size is the angle? How would the sextant look if the thread crossed the protractor at 90°?

Columbus used a sextant very similar to yours when he set out to reach India.

The straw on your sextant will aid you in looking at a star at night. To see a star through the straw, will you have to tilt your sextant? Will you be able to tell how far you tilted it? How?



Look at different stars in the night sky and find the angles needed to see them. If you were in Mexico City and looked at the same stars at night, would the angle of the sextant be the same?

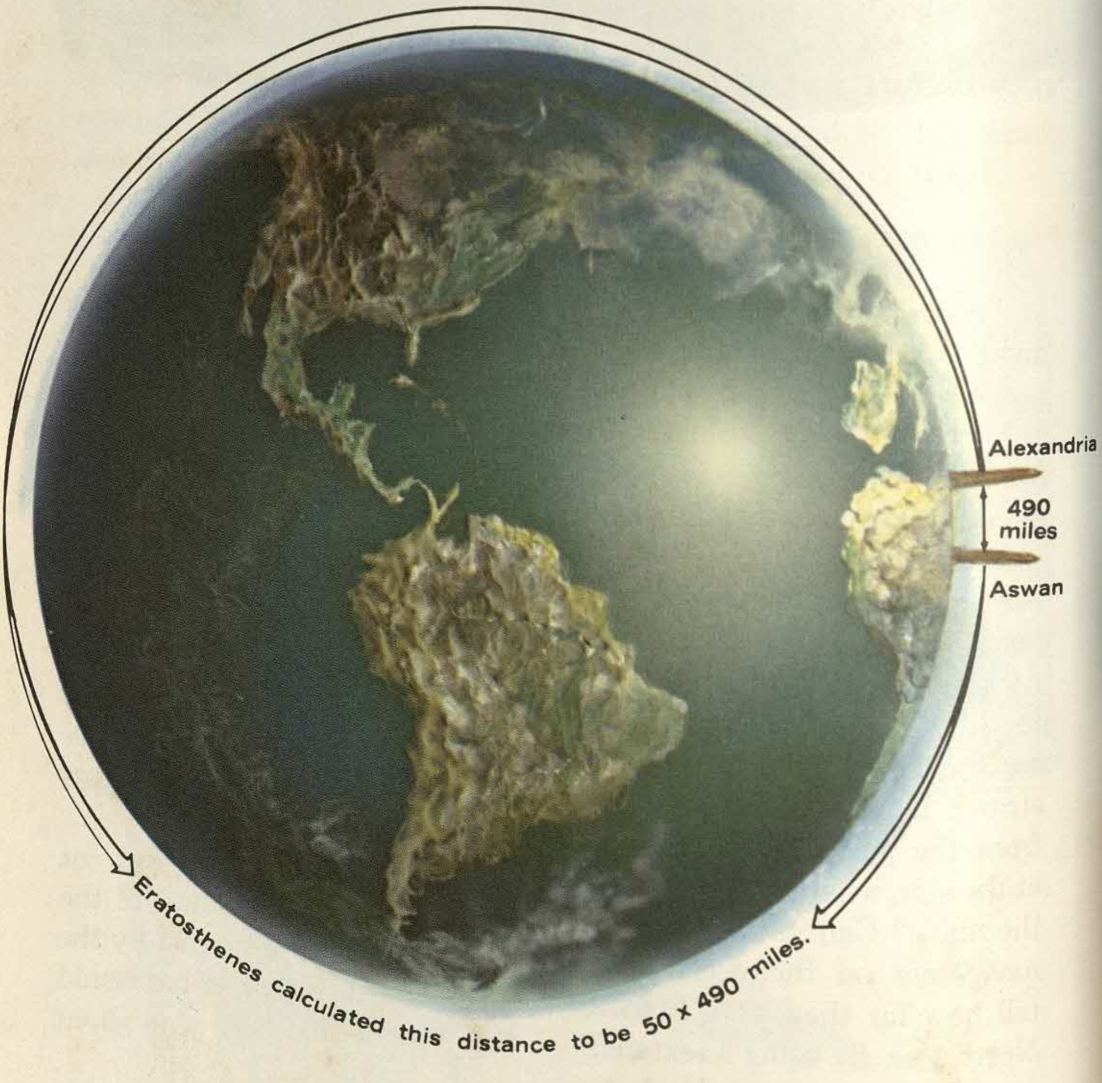
Pretend you were on the North Pole and you used your sextant to look at the North Star. At what angle would you have to tilt your sextant in order to see the North Star through the straw? If you sailed southward from the pole and kept looking at the star, what would happen to the angle? Can you explain how navigators on the ocean might tell how far they were from the North Pole by using a sextant?

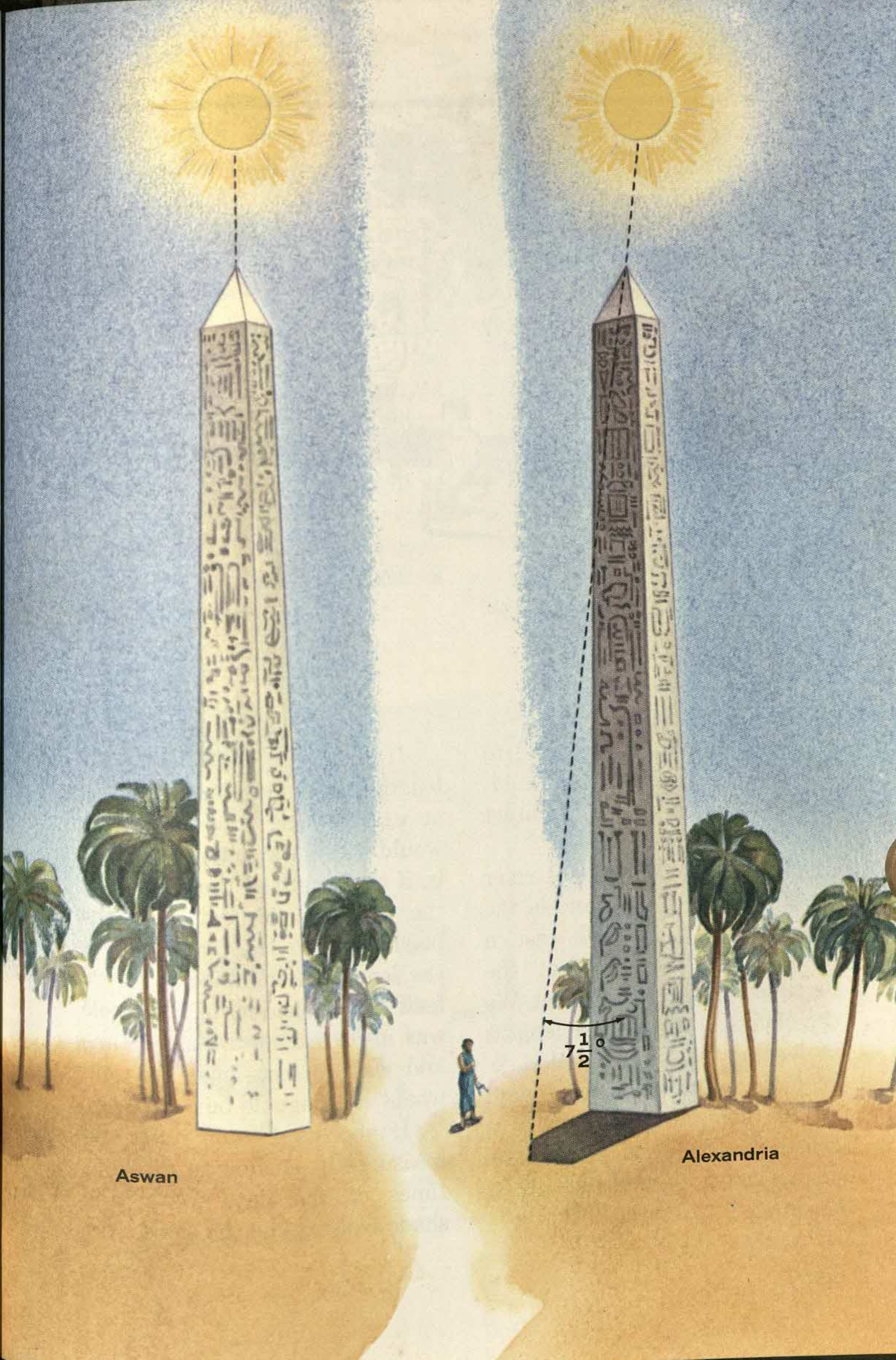
Shadows, Time, and Distance

As much as 2,000 years ago, some men believed that the world was round. You may already know that Eratosthenes, a Greek, calculated the size of the earth. He accomplished this by a series of careful observations. It was not necessary for him to measure this distance *directly*. Instead, Eratosthenes used *indirect measurement* to solve his problem. Let us review how he did this.

Eratosthenes read that at noon on the shortest day of the year no shadows were cast by the sun in Aswan, Egypt. W hat would this observation tell you about the position of the sun at that time? On the same day at noon, Eratosthenes saw that a tall building did cast a shadow in Alexandria, which was located 490 miles north of Aswan. He measured the angle that the sunlight made with the building and found that the sun was $7\frac{1}{5}$ degrees from overhead.

Eratosthenes knew that there were 360 degrees in a complete circle. He compared $7\frac{1}{5}$ to 360 and found it to be $\frac{1}{50}$ of a circle. He reasoned that if $\frac{1}{50}$ of the circle equaled 490 miles, then the entire circle must be 50 × 490. What answer did he get for the size of the earth? He was not exactly right, but he was very close.


Alexandria
490 miles
Aswan
Eratosthenes calculated this distance to be 50 x 490 miles.


7 1/2 °
Alexandria
Aswan

Shadows can also be used to calculate the height of tall buildings and trees. Again, indirect measurement is used.

If you stand a one-foot ruler upright on the playground in the late afternoon, it will cast a shadow. Let us say that the length of the shadow is 2 feet. We can compare these two lengths by writing them as a fraction, ½. When two numbers are compared in this way, the comparison is called a *ratio*. That is, the ratio of the length of the stick to its shadow is 1 to 2 or ½.

If you were to measure the length of a shadow cast by a tree at exactly the same time, you would obtain the same ratio. That is, if the length of the shadow of the tree was 40 feet, then the height of the tree would be ½ the length of the shadow, or 20 feet. If the shadow of a flagpole was measured at the same time and was 80 feet long, how tall would the flagpole be?

If you used your ruler and measured its shadow at different times of the day, would the shadow always be the same size?

Would the ratio be the same? If your ruler were one foot tall and the shadow it cast were three feet long, what would the ratio be? What would the shadow length of a 50-foot tree be at this time?

MEASURE Find the length of the shadow cast by an upright yardstick. Also measure the length of the shadow cast by a tall object nearby. A building, telephone pole, or flagpole will do. Can you calculate the height of the tall object? Measure several tall objects in this way and compare your answers with those of your classmates.

Indirect Measurements

Eratosthenes calculated the size of the earth using indirect measurement. You have measured the heights of tall objects using indirect measurement. Why must indirect measurement be used to calculate distances in space?

Many books will tell you that the moon is about 237,000 miles from the earth or that the sun is about 93,000,000 miles from the earth. How did men first calculate such distances? What methods did they use? In order to answer these questions, you will need to

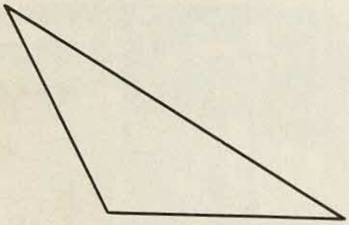
review some ideas about triangles and scale drawings.

Look at the triangles. How many straight lines make each triangle? How many angles are found in each triangle? If you were to measure each angle of a triangle with a protractor and add the angles together, what would the total be?

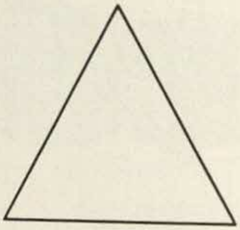
MEASURE Draw three triangles similar to the ones shown. Use a ruler and a sharp pencil. Carefully measure each angle of one triangle with a protractor. Add the 3 numbers together. What answer do you get? Do the same for the other 2 triangles. What do you discover? What answers did your classmates get? What can you say about *all* of the triangles that you measured? Do you suppose that this is true of all triangles you can draw?

EXAMINE Now look at the triangle on this page. Angle A is 70°, angle B is 45°. Can you calculate angle C without measuring it? Check your answer by measuring the angle with a protractor.

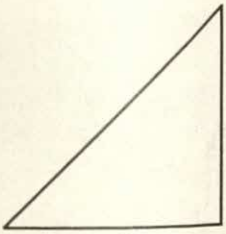
If another triangle had one angle of 35° and a second of 60°, how many degrees would there be in the third angle?



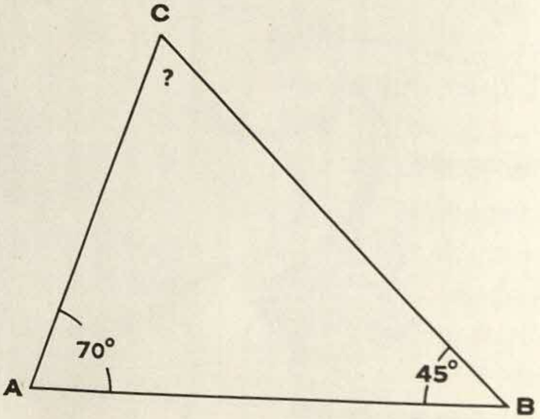
1

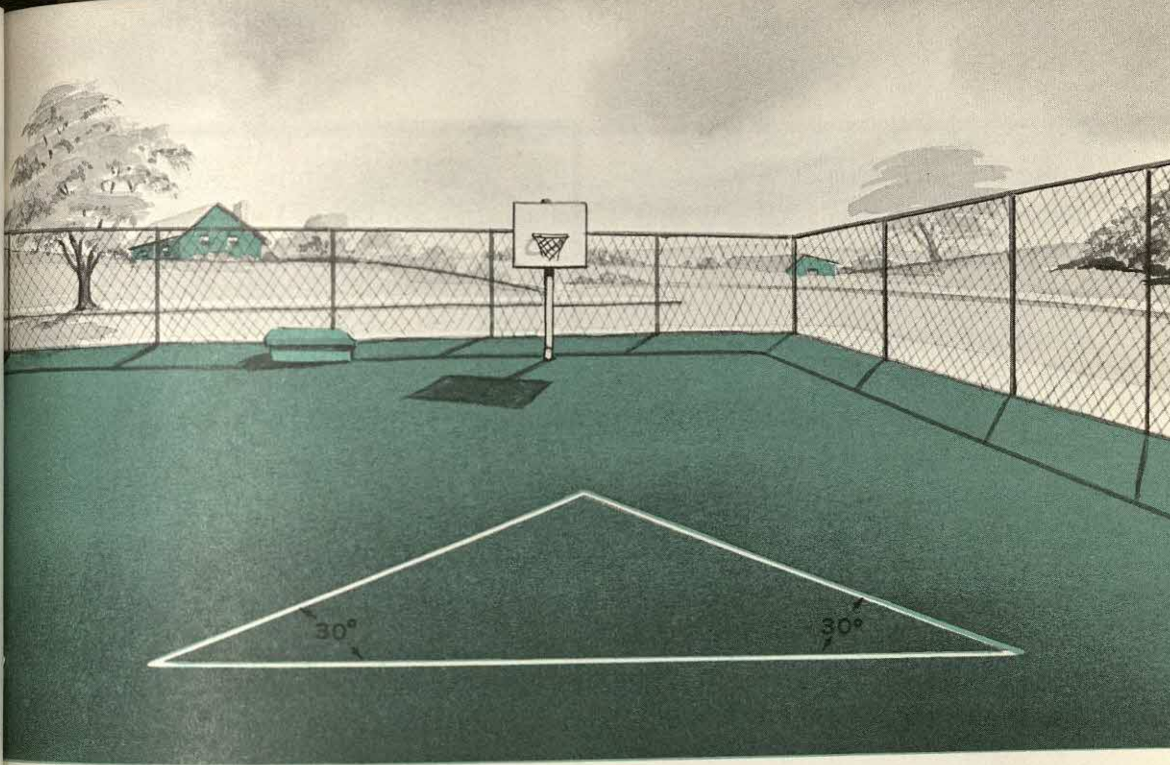


2



3





If you were told to draw a triangle that had two 45° angles in it, could you do it? Try it. Does your triangle look like the triangles of your classmates? What is similar and what is different?

If you were told to draw a triangle that had two 45° angles, one on each side of a 3-inch base line, could you do it? Do all the triangles drawn with these directions look the same? What information do you need to know about a triangle before you can draw it correctly?

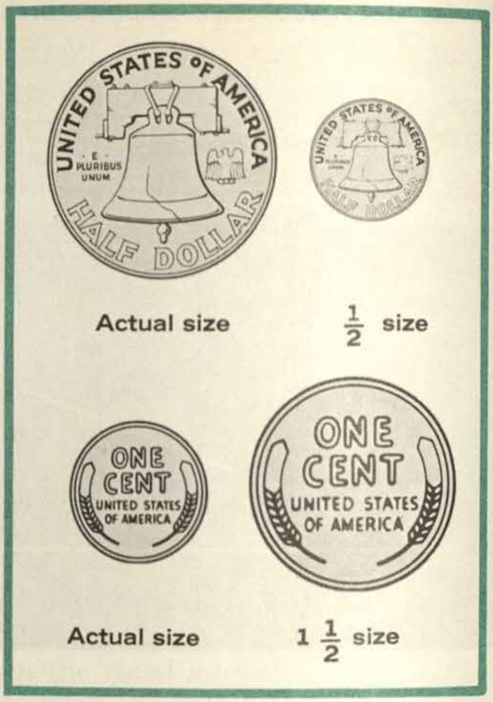
If you had a triangle drawn on your playground with a base line 30 feet long with two base angles of 30°, could you draw it on a piece of paper? If you made 1-inch stand for 10 feet, could you draw the triangle on the paper? Would the triangle have the same shape? What would be the only difference between the two? ☐☐

You can make a scale drawing of a box, triangle, your schoolyard, or a trip you took. If you make such a drawing, you will notice that every detail of the object, place, or distance is the same except the size.

In order to measure large distances on a small piece of paper, you need to make a scale drawing. The scale that is used must be a sensible one. For example, if you wanted to show a line that is

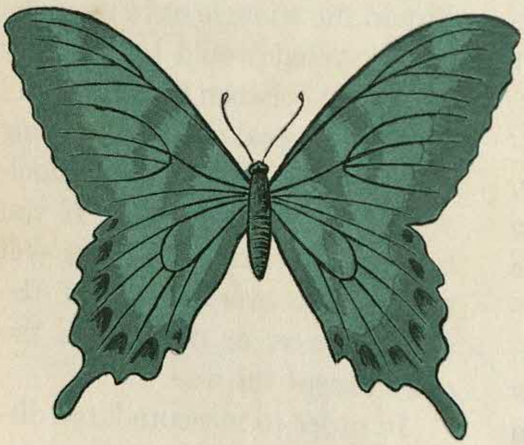
5 miles long on a small piece of paper, you could use a ruler to draw a 5-inch line and say that 1 inch = 1 mile. In this way, you have made some large thing fit in a smaller place. Your scale is 1 inch = 1 mile. Could you have also said that ½ inch = 1 mile? Or ¼ inch = 1 mile? When might smaller scales be used?

ACTIVITY Take a piece of paper that is 8½ inches x 11 inches in size. Draw lines on the paper to represent these distances: 3 miles; 100 miles; 400 miles; 2,000 miles; 60,000 miles.



Actual size $\frac{1}{2}$ size

Actual size $1\frac{1}{2}$ size



Actual size

$\frac{1}{3}$ size

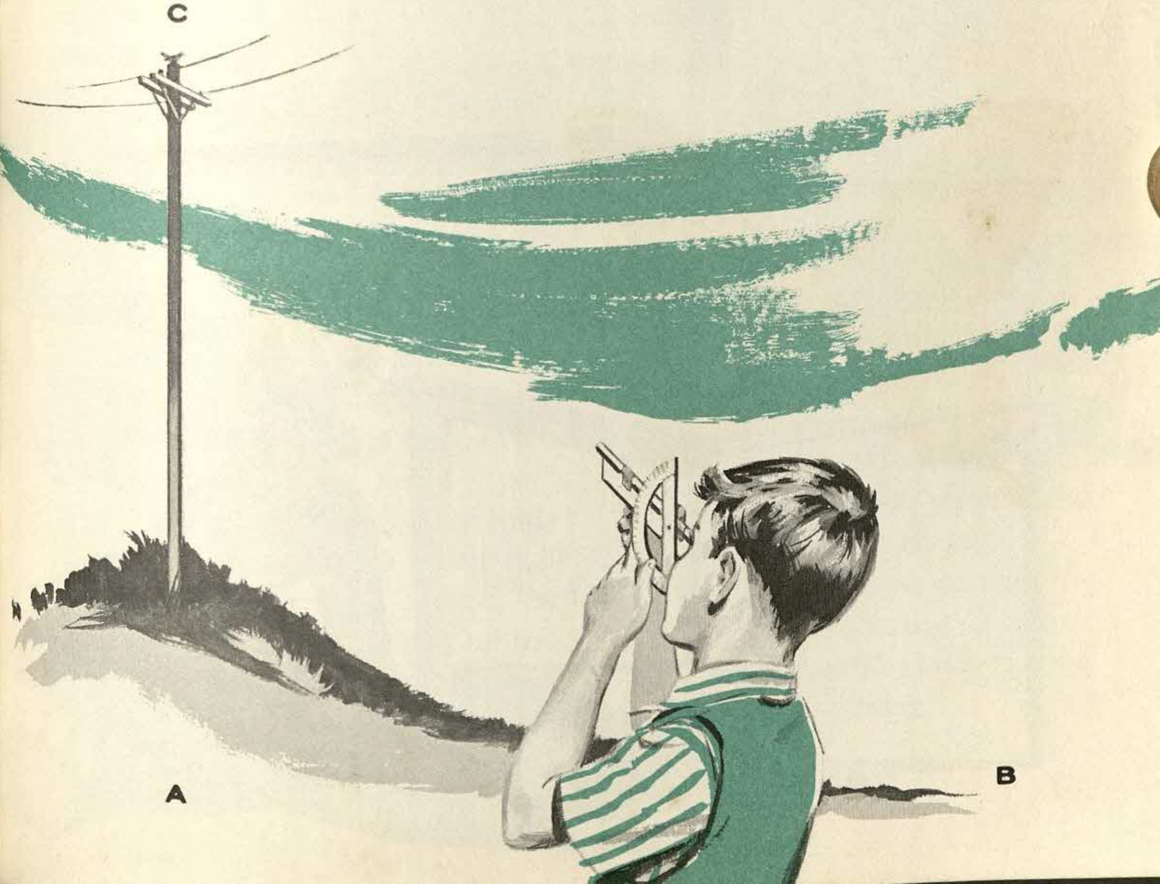
If someone looked at the lines you drew, would they know what they stood for? When you make a scale drawing, it is important to include an explanation of your scale. Look on different maps to find how the scale explanation is given. Give scale explanations for each of your drawn lines.

EXPLORE If you saw a bird sitting on top of a telephone pole, could you tell how far away it was from you without climbing the pole? Let us use the picture to see how the sextant, a knowledge of triangles, and a knowledge of scaling can be used to answer this question.

Do you see a triangle in the picture? The distance from A to B is the base line of the triangle. How could this distance be measured by the boy in the picture? Let us say that the boy found the distance to be 30 feet.

How could the boy find the number of degrees in angle ABC? How would you measure this angle? Let us say that the boy found angle ABC to be 52°. How many degrees are there in angle CAB? How do you know?

Do you have all the information you need to make a scale drawing of the triangle? What scale will you use?



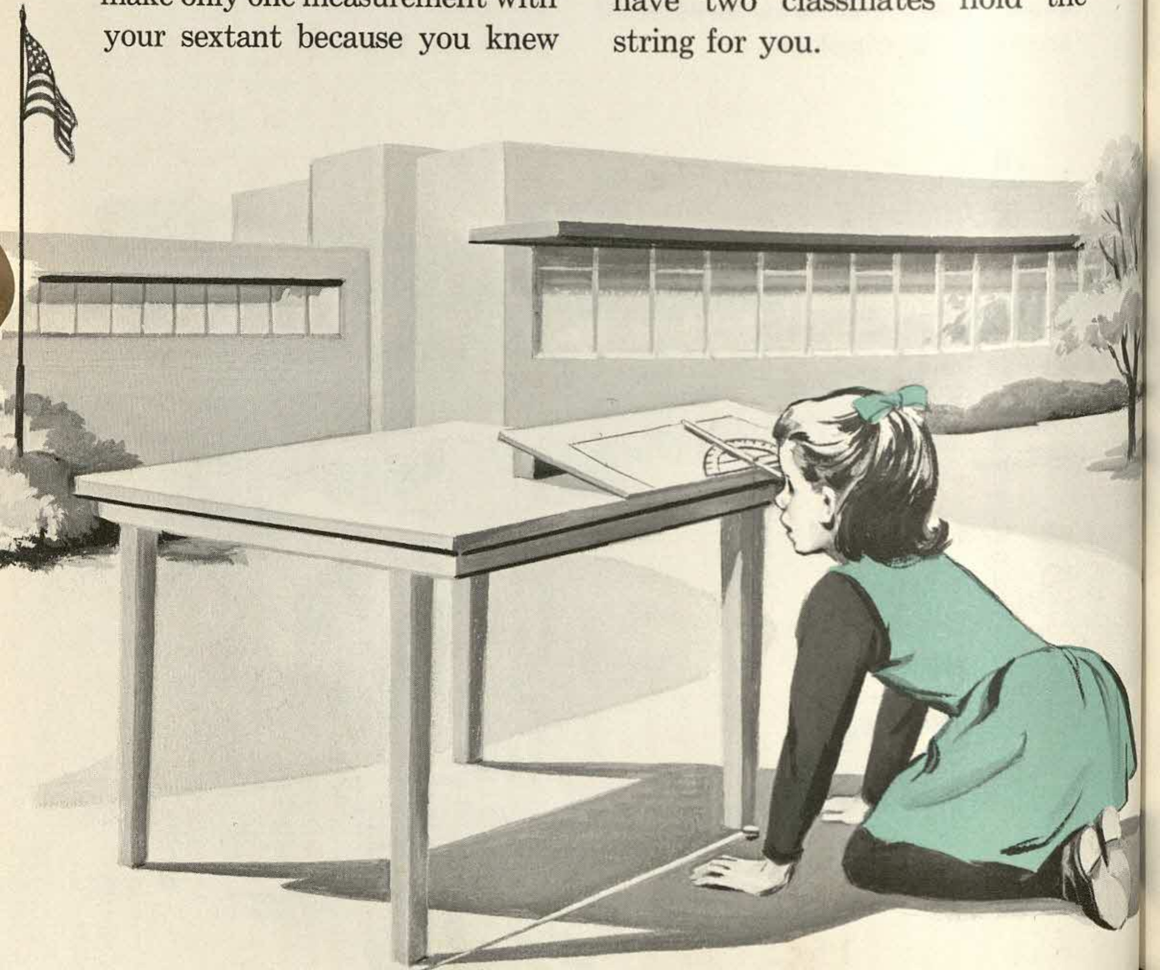
Use your scale drawing to answer these questions. How far is the bird from the ground? How far is the bird from the boy? Do you know how many degrees are there in angle BCA? □□

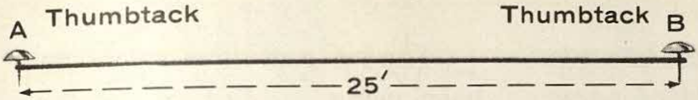
You have just measured the distance to an object in space.

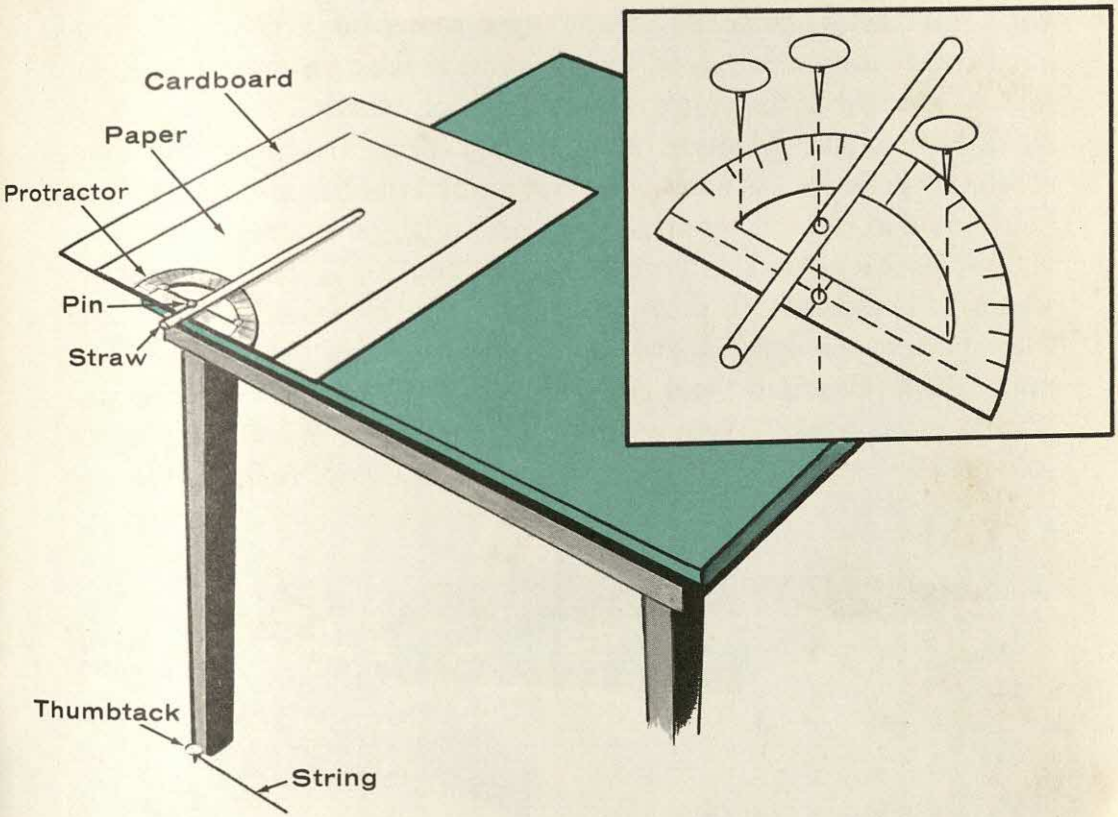
MEASURE Use your sextant and follow the procedure just described to measure the distance to the top of the flagpole at your school. See if you can also find the height of a nearby telephone pole or tall tree. □□

In the last activity you had to make only one measurement with your sextant because you knew what one angle of the triangle was without measuring it. Sometimes it is necessary to make more than one measurement because none of the angles are known. To see how this can be done, let us pretend that we want to measure the distance across a river without having to cross it.

MEASURE Plant two stakes exactly 25 feet apart. Measure the distance between them very carefully with a tape measure. Stretch a heavy string tightly between the stakes. If you cannot place the stakes in the ground, have two classmates hold the string for you.







Pretend that the line you have made is along the bank of a swift-moving stream. Station a third person on the other side of the "bank." He should be between the two ends of the string and about 50 feet away.

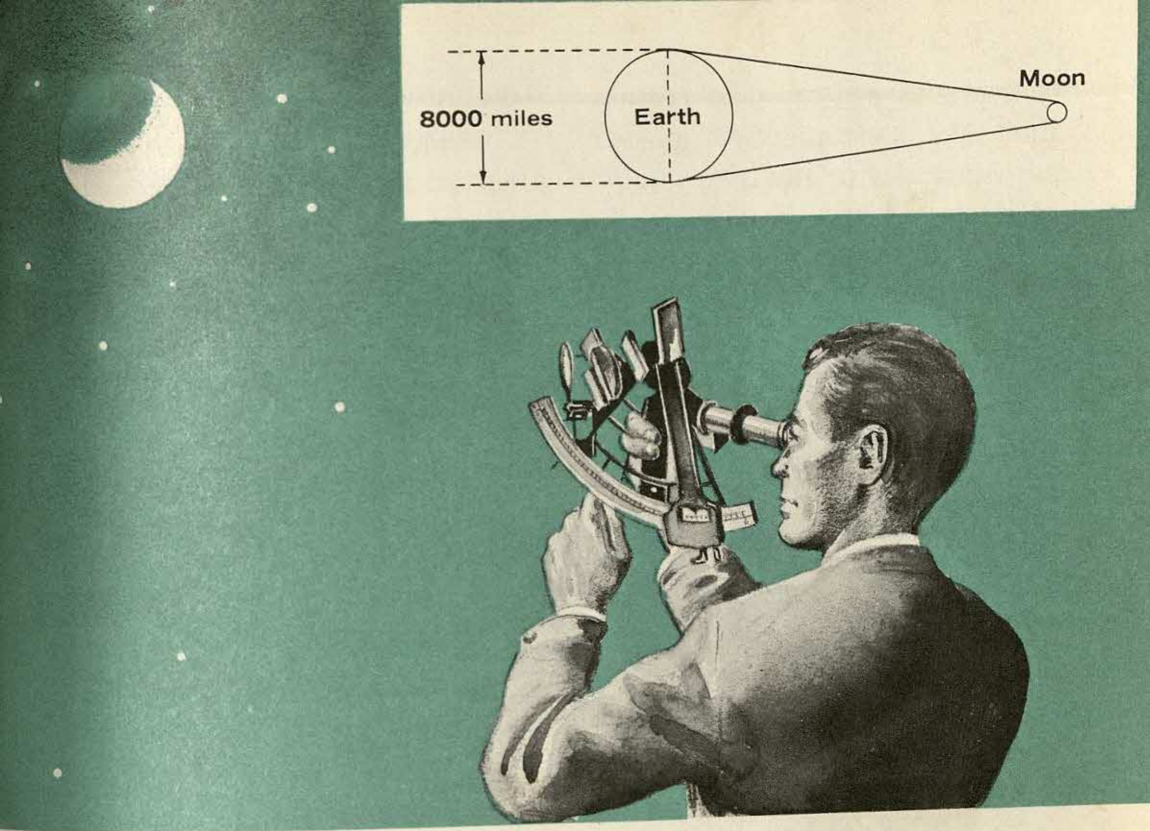
Set a sheet of lined paper along the edge of a small table. Place a protractor, straw, and other materials on the table as shown in the picture. Now place the table so that the center of the protractor is directly over one stake. Make sure the back legs of the table are on the string as shown. Look through the straw and sight the person on the other bank. Mark the paper and measure this angle. Move the table and materials to the other stake and repeat the procedure.

Do you now have enough information to make a scale drawing? What would make a good scale for this drawing?

Draw the scaled base line near the bottom of a sheet of paper. At each end of the base line, use your protractor to draw the angles you measured. Extend the lines which form the angles to make a triangle. Measure the shortest distance between the base line and the angle opposite it. How far is it across the "river"? Use a tape measure to measure the shortest distance between your third classmate and the string "river bank." Were your calculations correct? ☐☐

The indirect method you have been using to measure distances is called triangulation (tri-*ang*-gyoo-LAY-shun). When triangulation is used to determine locations on earth, the process is called surveying. Surveying is not new. It is believed to have been used in Egypt in ancient times.

ACTIVITY Repeat this activity using larger and smaller base lines. Are your "surveying" answers close to the measured distances? When the tools you use are not carefully made, errors are



bound to creep into your measurements. Can you think of ways to improve your accuracy? Can you design a better instrument by using a larger protractor and longer straws? □□

As you have seen, it is possible to measure distances by using a triangle. All that is necessary is to know the length of the base line and the number of degrees in the two base angles. This method is satisfactory for measuring distances on earth. Can it be used to measure distances from the earth to other objects in space? Can triangulation be used to measure the distance between the earth and the moon?

The shorter the base line is, the closer the base angle will be to 90°. For objects that are a great distance away, a long base line is necessary. The moon is thousands of miles away from the earth, so the longest base line possible is needed. What do you think the largest possible base line could be?

The earth is a slightly flattened sphere about 8,000 miles in diameter. By measuring the distance to the moon from opposite sides of the earth, a base line of 8,000 miles can be obtained.

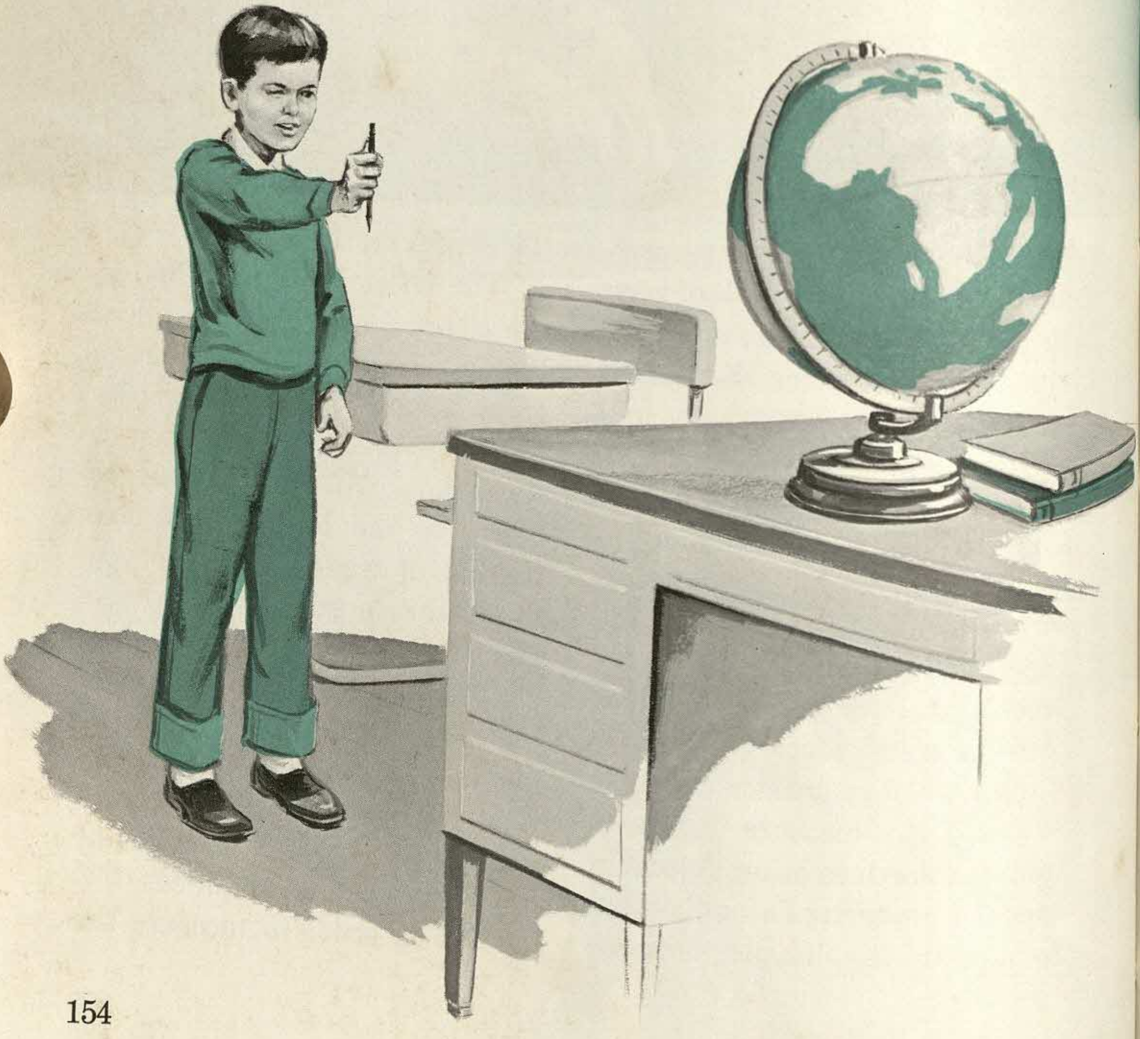
But in order to measure the

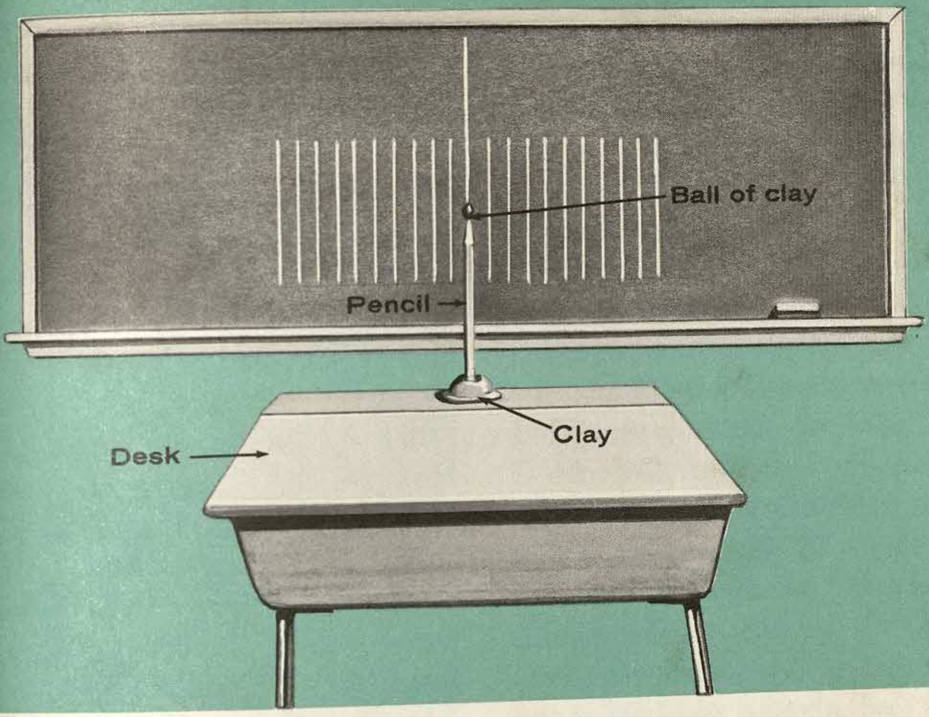
base angles, we must be certain that our instrument is placed perpendicular to the base line at each end. You were able to do this in the last activity by placing the legs of the table directly on the string. How can we be certain of our position when measuring from opposite sides of the earth? In order to solve this problem, it is necessary to know something about the visual effect called parallax. Let us consider it.

The Parallax Effect

OBSERVE Hold a pencil upright at arm's length. Close your left eye and line up the pencil with an object on a far wall. Hold the pencil steady in this position as you open your left eye and close your right eye. What do you observe about the positions of the pencil and the object on the wall?

The apparent shift of position that you observed is known as the parallax effect. What causes it?





Have someone measure (very carefully, please) the distance between the pupils of your eyes as you look straight ahead. What is the distance between your eyes? As you make observations with your right eye and then your left, you look at the far object from two slightly different positions. For this reason, the pencil seems to shift its position in relation to the background. Does parallax change as the distance to the far object changes?

DISCOVER Place a small clay ball on the point of a pencil. Stand the pencil and ball upright on a desk in the center of the room. Use clay to hold the pencil in place. Draw a series of vertical lines one inch apart on the chalkboard. Stand back about 3 feet from the clay ball. Find the parallax by counting the number of spaces the ball seems to shift. Repeat this several times as you move back from the ball about two feet each time. Make a table of your results.

Distance from pencil	Parallax
3 ft.	
5 ft.	
7 ft.	
9 ft.	
11 ft.	
13 ft.	

Does the parallax change as the distance from the observer to the object changes? How does the parallax change? Do you think it is possible to arrive at a distance where there would be *no* parallax?

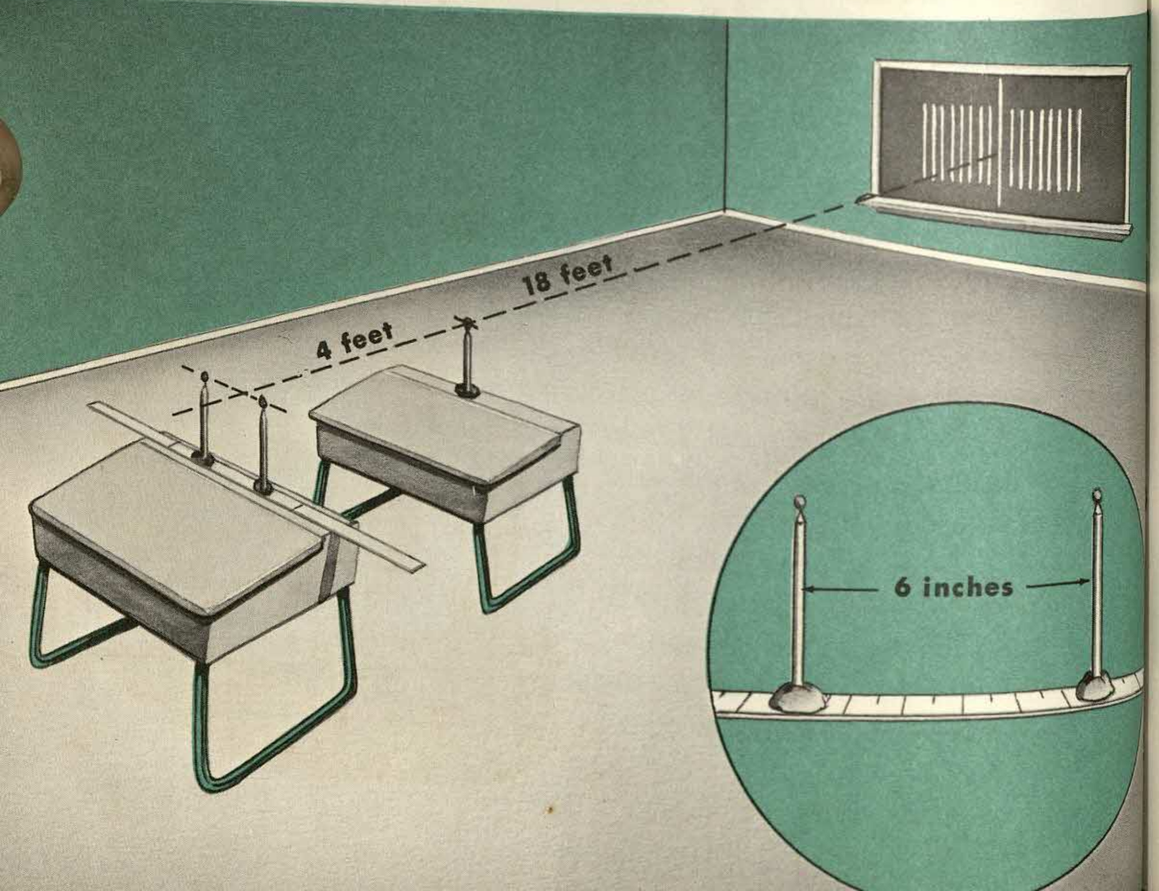
Notice that in each case during this activity you were sighting from a set of fixed points, the positions of your eyes. What would the parallax effect be if your eyes were further apart?

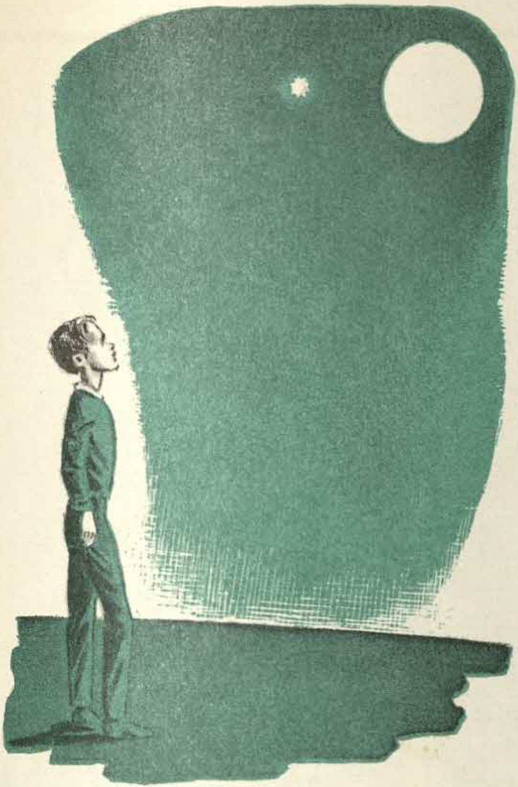
EXPLORE Place a clay ball on a desk. Set the desk about 18 feet from the marks on the chalkboard. Lay a yardstick on a second desk about 4 feet behind the clay ball. Stand 2 pencils upright on the yardstick 6 inches apart. Make your sightings from behind each of the pencils. Record the parallax.

Move the pencils so they are 12 inches apart and measure the parallax. Now place the pencils 18 inches from each other. Record the parallax.

Study your measurements. How is the distance between sighting positions related to the amount of parallax obtained? □ □

You have discovered two important factors involved in parallax. First, the farther an object is from the observer, the smaller is the parallax. Second, the greater





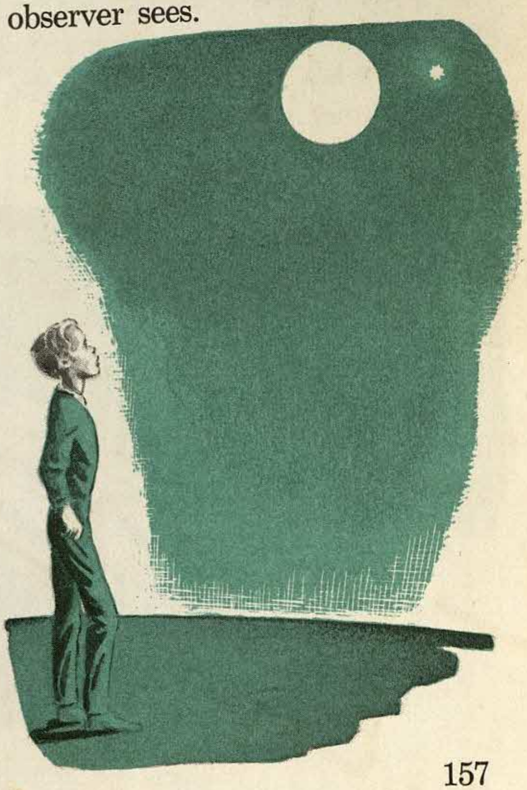
the distance between the positions from which the object is seen, the larger is the parallax effect.

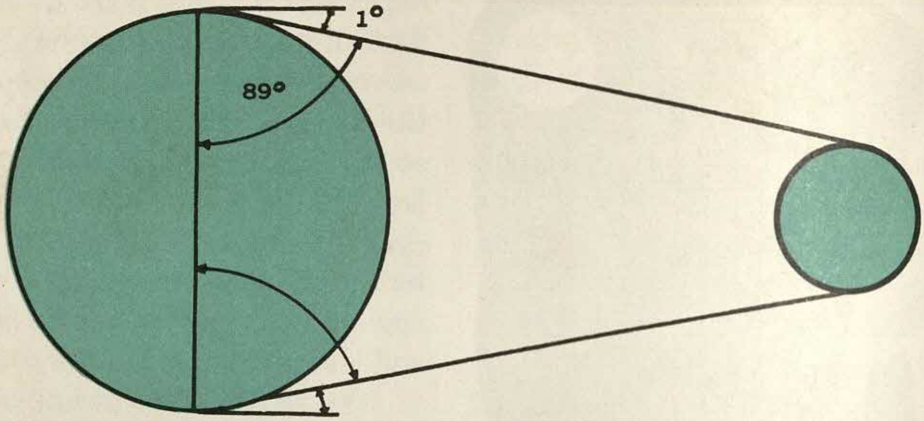
Measuring Distances in Space

How can this knowledge help us to find the distance to the moon? Remember, our original problem was to determine a way to measure the angle on our base line when measuring from opposite sides of the earth. For this, we need to draw a line perpendicular to the base line, the earth's diameter.

You noticed, in triangulation, that the farther an object is from the observer, the closer the base angle is to 90°. The stars are billions of miles from the earth. If two observers stand on the opposite sides of the earth and look at the same distant star, they are both looking in the same direction. Because stars are so very far away, each observer shows an angle of 90° between his base line and line of sight to the star.

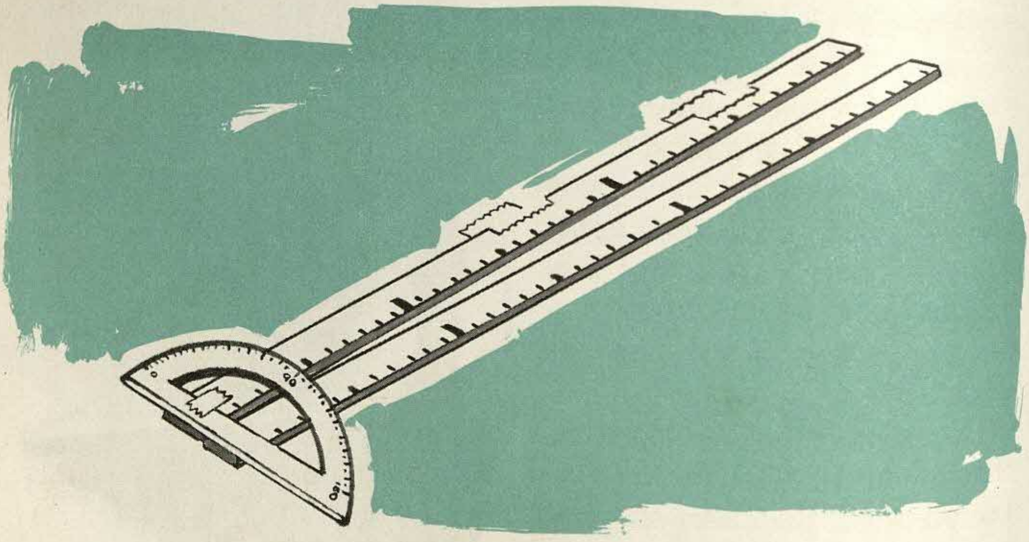
The next step is to find the parallax angle for the moon—the angle made when a line is drawn from each observer to the moon. The moon is much closer than the star, so each observer sees the moon in a different position in relation to the star. The pictures on this page show you what each observer sees.





There is a difference of 1° between the star and the moon for each person. Therefore, the base angle for each person is 89°. Can you see that the parallax angle for the moon is 2°? Why must this be true? With the information you now have, you can calculate the distance to the moon.

MEASURE Obtain two yardsticks that are not bent or warped along their edges. Tape one yardstick flat on a smooth, hard surface such as a desk or table top. Place a protractor on top of this yardstick along the 90° line as shown. Tape the protractor to the yardstick so that it will not move.



Bring the second yardstick up to the first one, under the protractor. Use the protractor to make an angle of 2° between the yardsticks. Do this carefully. When you are satisfied, tape the second yardstick down.

With a ruler, measure the distance between the yardsticks until you find where they are exactly one inch apart. Is this near the 30-inch mark? If one inch represents 8,000 miles (the diameter of the earth), what is the distance from the earth to the moon? □ □

The method you have used to find the distance to the moon is one of the ways by which astronomers find the distance to nearby stars. Our sun is the closest star to earth. How could its distance be measured?

About 250 B.C., Aristarchus (ar-is-TAHR-kus), a Greek astronomer, made a useful observation that provided a very large base line for measuring the distance to the sun. He noticed that every few weeks the moon appeared to be exactly half light and half dark. Aristarchus thought that at these times the angle formed by the moon between the sun and earth must be exactly 90°.

Do you remember how you measured to the top of a flagpole using your sextant? What was your base line? What is Aristarchus' base line? What angle did you know without measuring it? What angle did Aristarchus know without measuring it? What angle did you need to measure? What angle did Aristarchus need to measure? How do you think he did this? Do you think he needed to use a scale drawing? Why?

Many stars are so very far away that an even longer base line must be used. To measure the parallax angle of a star, astronomers use the diameter of the earth's orbit around the sun as the base line. This distance is nearly 186 million miles.

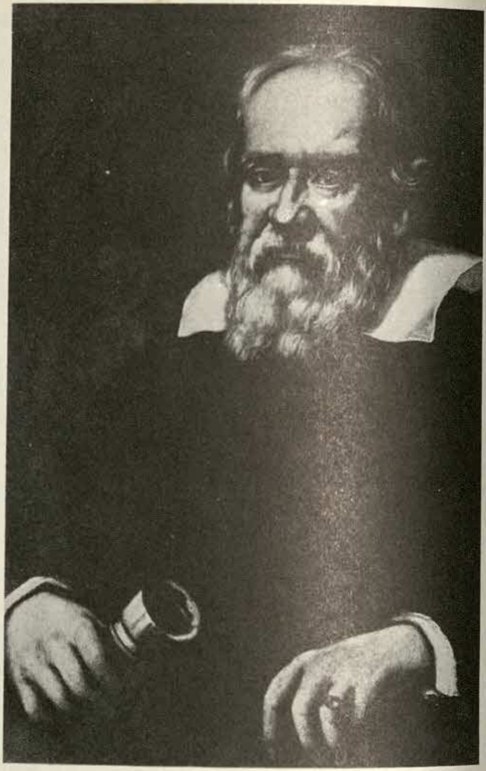
Man Extends His Vision

By the beginning of the seventeenth century, men had learned a great many things about the earth and the heavens. Until that time, they had to rely on their

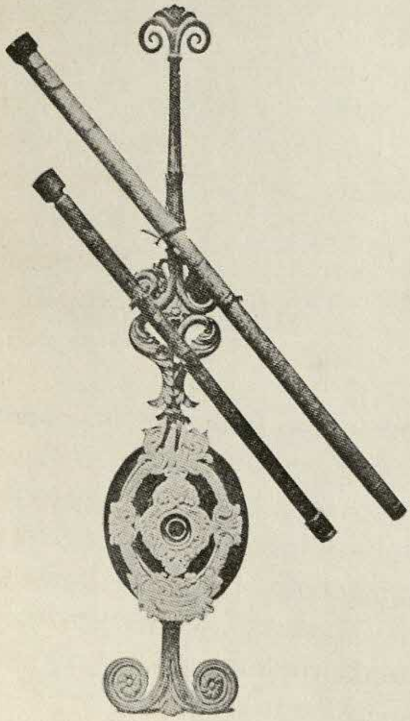
own powers of observation and on the use of simple tools.

In 1608 something happened that paved the way for great new developments in astronomy. In that year a Dutch lens maker, named Hans Lippershey (LIP-ers-hy), happened to hold up to a window two lenses he had been working on. Instead of looking through each one separately as he usually did, he happened to glance through both of them at the same time. Much to his amazement, a distant windmill seemed to appear in his front yard.

OBSERVE Obtain two lenses or magnifying glasses. One must be more powerful than the other. Hold the lenses together with the higher-powered one about an inch from your eye. Look through the lenses and slowly move the lower-powered lens away until the image you see is clear. Describe what you see. ☐☐

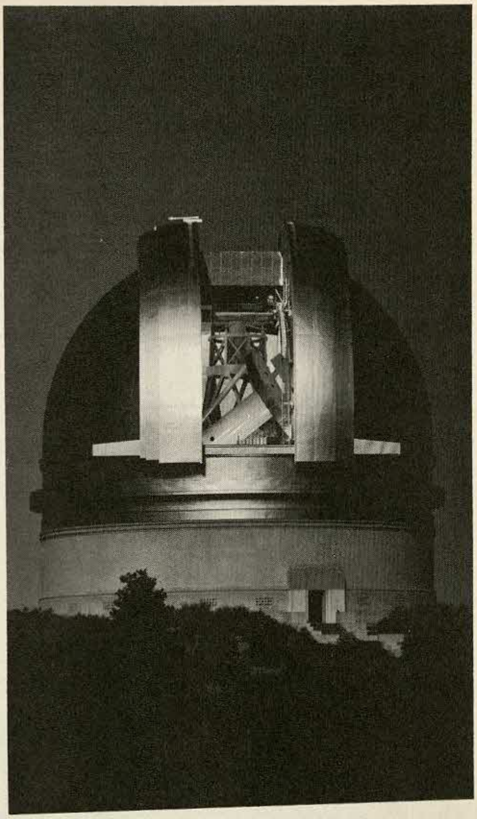


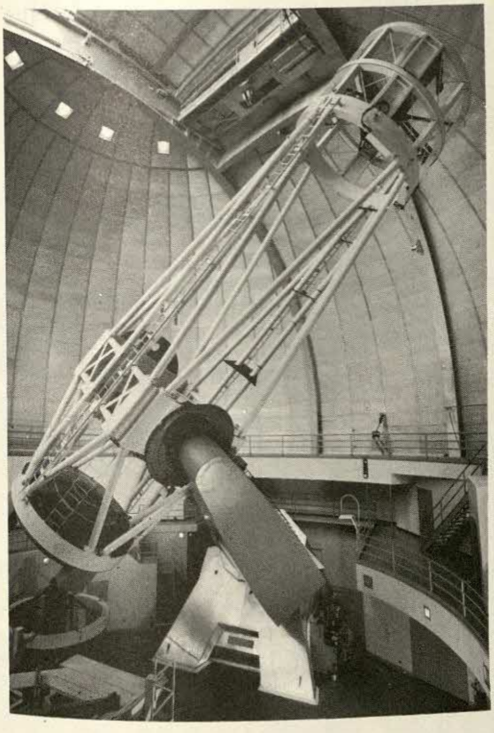
When Galileo, the great Italian scientist, heard about Lippershey's discovery, he became very interested. Using his knowledge of lenses, he was able to develop an instrument for "seeing at a distance." From this simple beginning developed one of man's most useful instruments, the telescope. Galileo is credited with having developed the first astronomically useful telescope in the year 1609. From this point on, man had a tool that could extend his vision farther than he had ever dreamed.



Today three of the largest telescopes in the world are in the United States. At the Lick Observatory on Mount Hamilton in California, there is a telescope with a mirror 120 inches in diameter. This is the second largest optical telescope in the world. It has been in use since 1888.

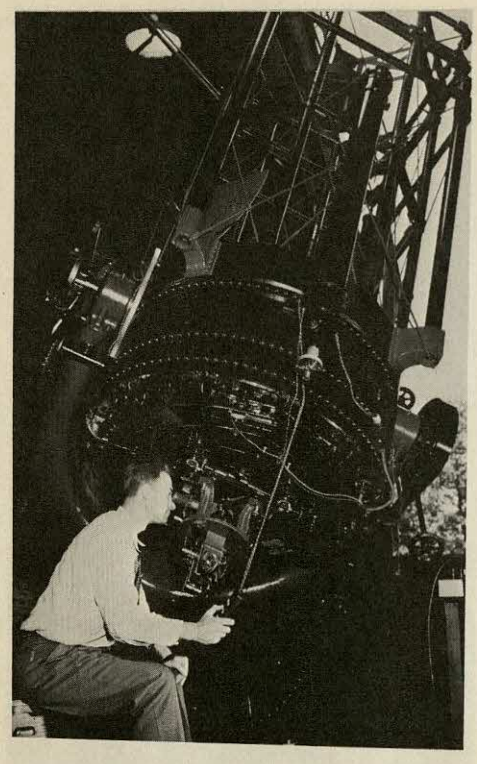
In 1940, the Mount Wilson Observatory was opened at a location about 5,000 feet above Pasadena, California. The telescope there has a 100-inch mirror and the whole telescope is mounted in a dome about 100 feet high. This giant telescope can gather about 250,000 times as much light as the naked eye. The light-gathering power of a telescope is measured in terms of the area of the human eye. It is the ratio of the area of the telescope's mirror or lens to the area of the pupil of the eye.





The largest telescope in the world is the Hale telescope. It is housed at Mount Palomar Observatory near San Diego, California. Its mirror, 200 inches in diameter, can gather 1 million times as much light as the naked eye. With it, stars about 600 million light-years away can be seen.

OBSERVE On a clear, dark night look at a bright starry patch of sky. Then look at the same part of the sky with binoculars or with a small telescope. Can you see more stars than you saw without the instrument? Imagine how many you could see with one of the giant telescopes!



The Camera

The telescope is one of man's most important instruments for the study of space. But without another tool, the camera, it would be impossible to make permanent records of man's observations.

By attaching a camera to the eyepiece of a telescope, it is possible to make a permanent record of what is "seen." The picture can be studied, measured, catalogued, and stored for future use.

One of the most important uses of the camera as a tool for exploring space is in photographing very faint objects. The human eye can only gather a certain amount of light. It cannot store light and build up an image over a period of time. But photographic film can. Film can be exposed to the light from a faint object for several hours. In this way light coming from the object can be recorded. When the film is developed, an image of the faint object can be seen. What happens when you make a time exposure of the night sky?

ACTIVITY Do this activity at night in an area where there is no stray light from street lights or automobiles. Place a camera on a tripod or other sturdy support. Adjust the camera so that it is facing in the direction of the North Star. Lock the shutter in the "open" position and leave the camera undisturbed for several hours. When the film is developed you should see streaks of light that are the trails of the stars you have photographed. Why do the stars show up as streaks instead of as pin points of light? ☐☐

In order to overcome the problem of star motion, modern telescopes are placed on sturdy, movable platforms. Once the camera is "fixed" on a star, the telescope follows the star across the sky. In effect, it keeps the star motionless for the camera.

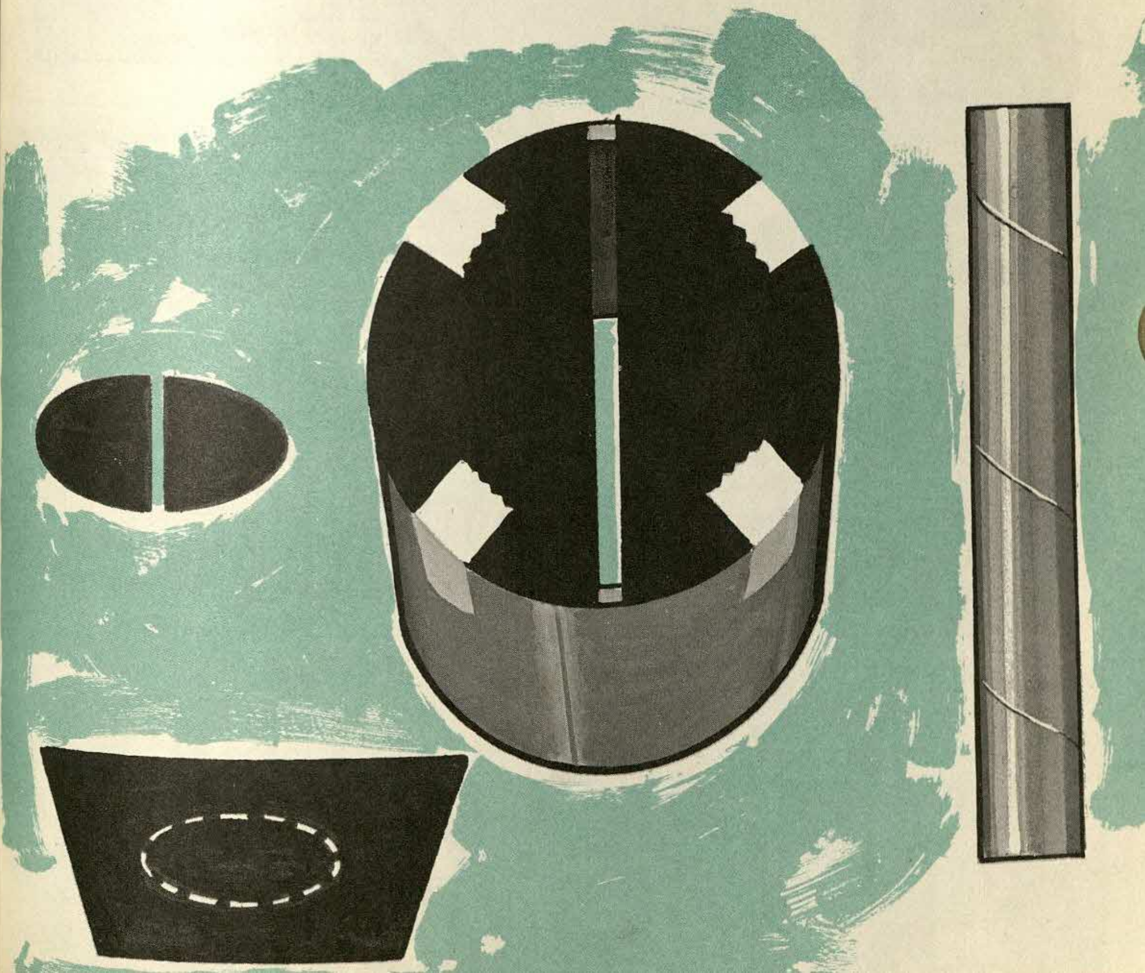
The Spectroscope

A spectroscope is another instrument that can be attached to a telescope. This instrument is considered to be one of man's most important and useful tools for the study of space. With it, man has been able to learn the chemistry of the stars.

CONSTRUCT To make a simple spectroscope, cut a circle of black paper the same size at the end of a cardboard tube. Cut this circle in half. Tape one half of the circle onto one end of the tubing. Tape the second half next to the first, but leave a narrow slit between the two pieces as shown.

Point the tubing at a bright light. Look through the open end of the tubing at the slit. The slit should be straight up and down.

Obtain a piece of diffraction grating from a scientific supply house. A grating usually has on it from 15,000 to 30,000 parallel lines per inch. When light passes through the grating, the lines cause the light to spread out into a band of colors. This band of colors is called a spectrum.



Hold the grating up to the open end of the tube. Look through the grating at the slit at the opposite end. Slowly turn the grating until you see a bright color band on each side of the slit. This indicates that your instrument is properly adjusted. Tape the grating securely to the tubing in this position. How can a spectroscope be used to analyze the substances of which the sun and other stars are made?

OBSERVE Look through your spectroscope at a lighted fluorescent tube. Do you see a spectrum on either side of the slit? Look carefully at the yellow, green, and blue portions of the spectrum. Do you see narrow bright lines? These lines are caused by the glowing gases in the tube.

Straighten a paper clip and make a small loop at one end. Hold the loop in a flame until it does not color the flame. Dip the loop in baking soda and hold it in the flame for a while. What color is the flame? Watch the flame through your spectroscope. Describe what you see. ☐☐

Every element produces its own characteristic spectrum when it is heated to a point where it glows and gives off light. Thus, a spectroscope can be pointed at a glowing body and actually help to determine its composition. Baking soda contains the element sodium. The yellow line you saw in the spectroscope was the spectrum of sodium.

DESCRIBE Clean the loop in the flame. Wet it slightly and dip it into some chalk dust. Hold it in the flame and examine the flame through your spectroscope. Describe the spectrum you see. This is the spectrum of calcium.

When you looked at the fluorescent tube through the spectroscope, was its spectrum like that of sodium or of calcium? ☐☐

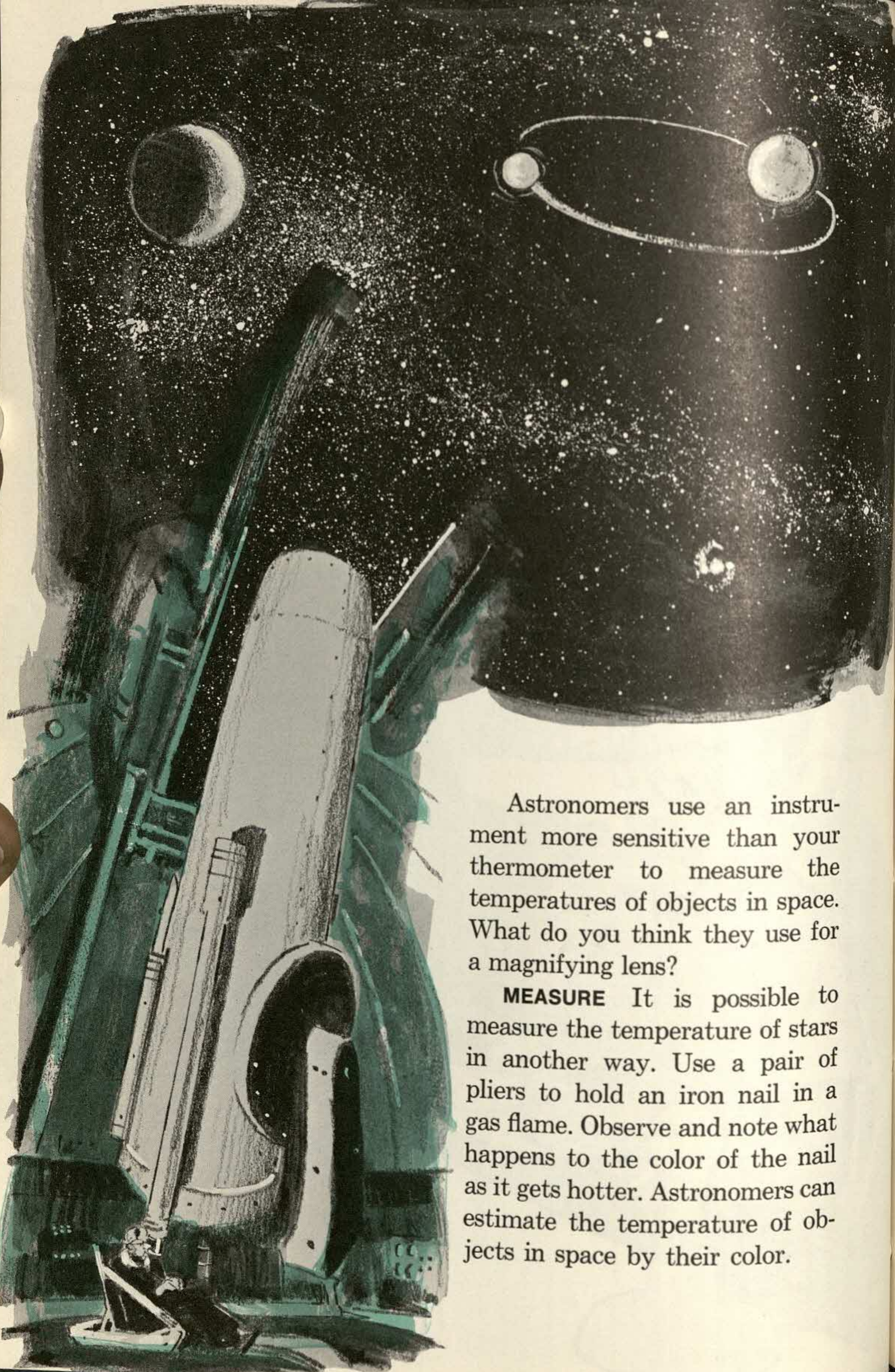
The spectrum of each known element has been photographed. By comparing these color patterns with the spectrum of a star, astronomers can determine what elements are present in the star.

Measuring Temperatures

No one has ever been to the moon or the sun to measure their temperatures, yet it is possible to find out their temperatures

RECORD Obtain a magnifying glass, a thermometer, and a bright electric light. Turn on the light and hold the thermometer about a foot away from it for about three minutes. Record the temperature reading. Now hold the magnifying glass so that the light from the electric light focuses on the bulb of the thermometer. After three minutes, record the temperature.

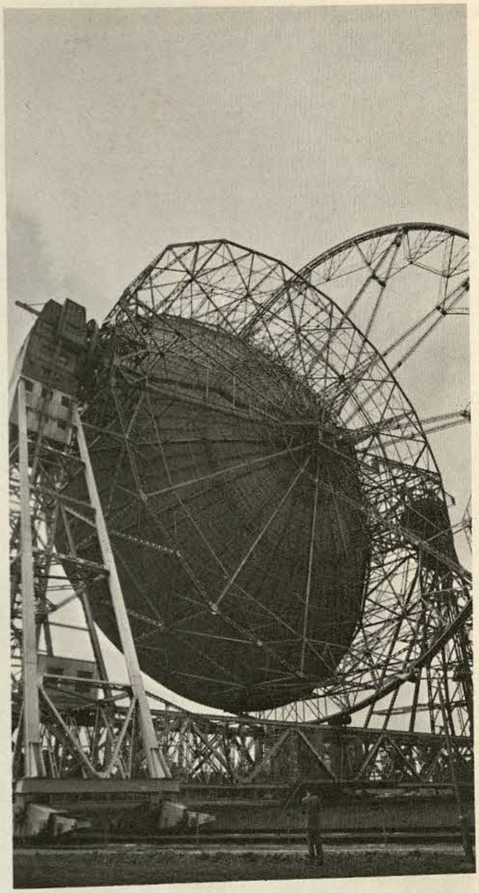
Record the temperatures at a greater distance from the light. How does the greater distance affect the temperature? ☐☐



Astronomers use an instrument more sensitive than your thermometer to measure the temperatures of objects in space. What do you think they use for a magnifying lens?

MEASURE It is possible to measure the temperature of stars in another way. Use a pair of pliers to hold an iron nail in a gas flame. Observe and note what happens to the color of the nail as it gets hotter. Astronomers can estimate the temperature of objects in space by their color.

Radio Telescopes

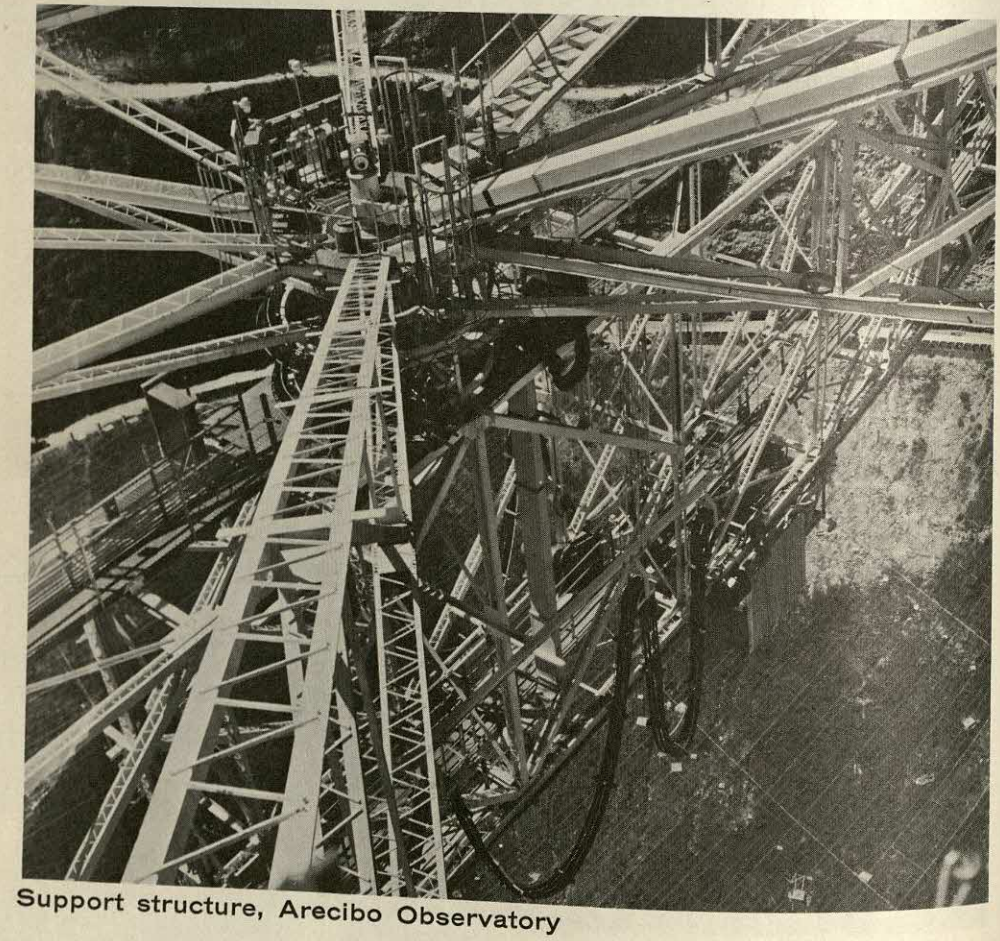


In the early days of radio, radio operators often noticed static they could not account for.

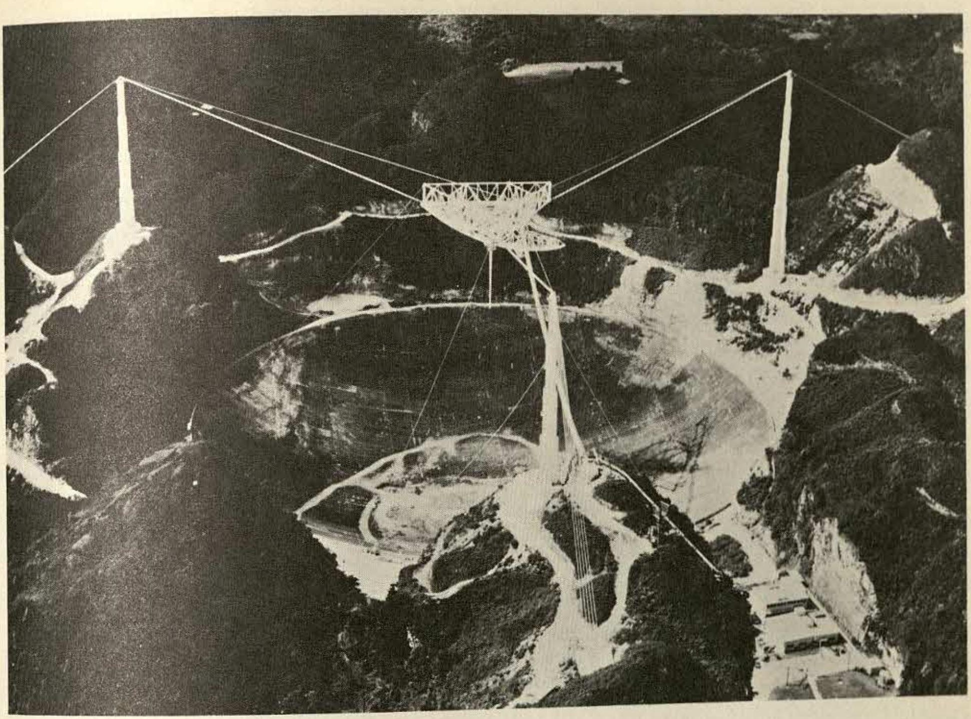
ACTIVITY Turn on a portable radio and tune it to a quiet place on the dial. Attach a wire to a dry cell and scratch the other terminal with the loose end of the wire. What do you see? What sound do you hear from the radio? In a similar manner, many objects in space send out radio waves that can be picked up on radio instruments. ☐☐

Karl Jansky, an engineer at the Bell Telephone Laboratories at Holmdel, New Jersey, was the first to identify the static. In 1931, he announced that the hissing static noises were radio waves coming from outer space.

There was excitement among astronomers. If large enough radio antennas could be built, the astronomers could learn about the stars and other objects in space by studying the radio waves they give off. Such antennas, up to 250 feet in diameter, were built and installed in several places in the United States, England, Australia, and other countries. They are called radio telescopes.



Support structure, Arecibo Observatory



View of Arecibo Observatory

In November 1963, a radio telescope 1,000 feet in diameter began operating in Puerto Rico. It is so powerful that it can pick up radio waves from stars that are 12 billion light-years away.

With a transmitter attached, a radio telescope can be used to explore the planets with radar. Radio waves are sent out, reflected from the planet, and received by the radio telescope.

There are several types of radio telescopes. All gather radio signals from space and focus them. The energy of the signals is changed into electricity which operates a pen. The pen moves across a moving piece of paper and traces lines which can be interpreted by astronomers.

Radio signals from space are very faint. Increasing the diameter of the receiver increases the gathering and focusing power of the radio telescope.

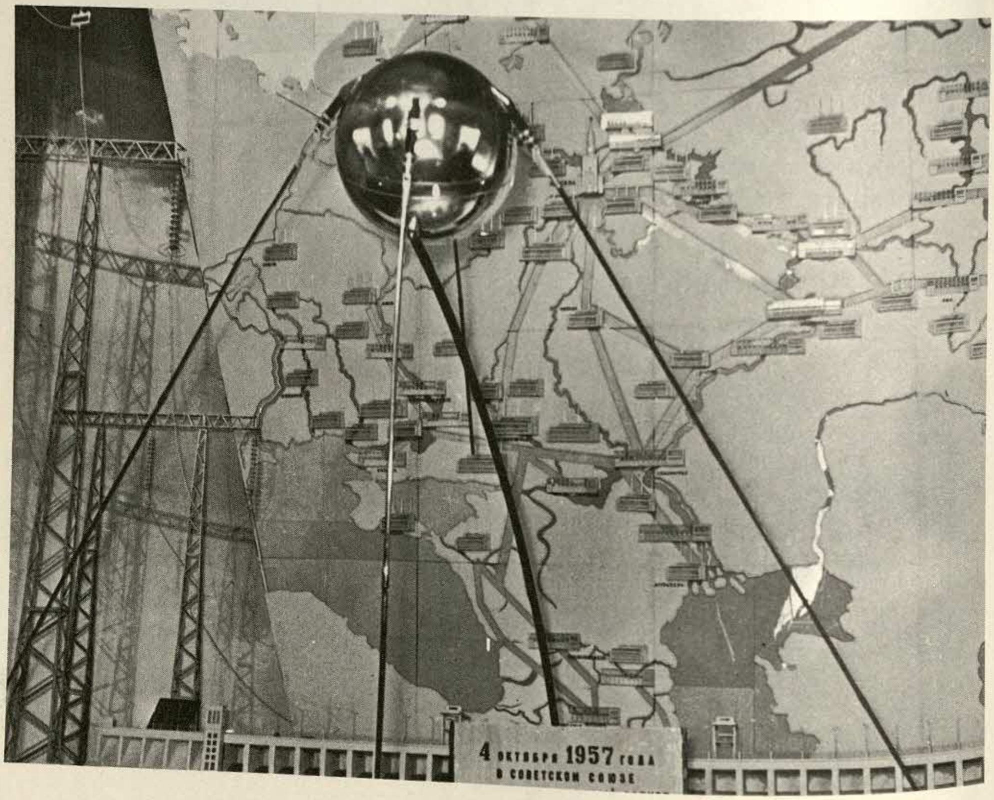
Radio telescopes have advantages over optical telescopes. Your radio operates as well during the day as during the night. Can optical telescopes be used to examine distant stars in the daytime? Does a cloudy sky affect observations with optical telescopes? Do you think clouds would affect the operation of radio telescopes?

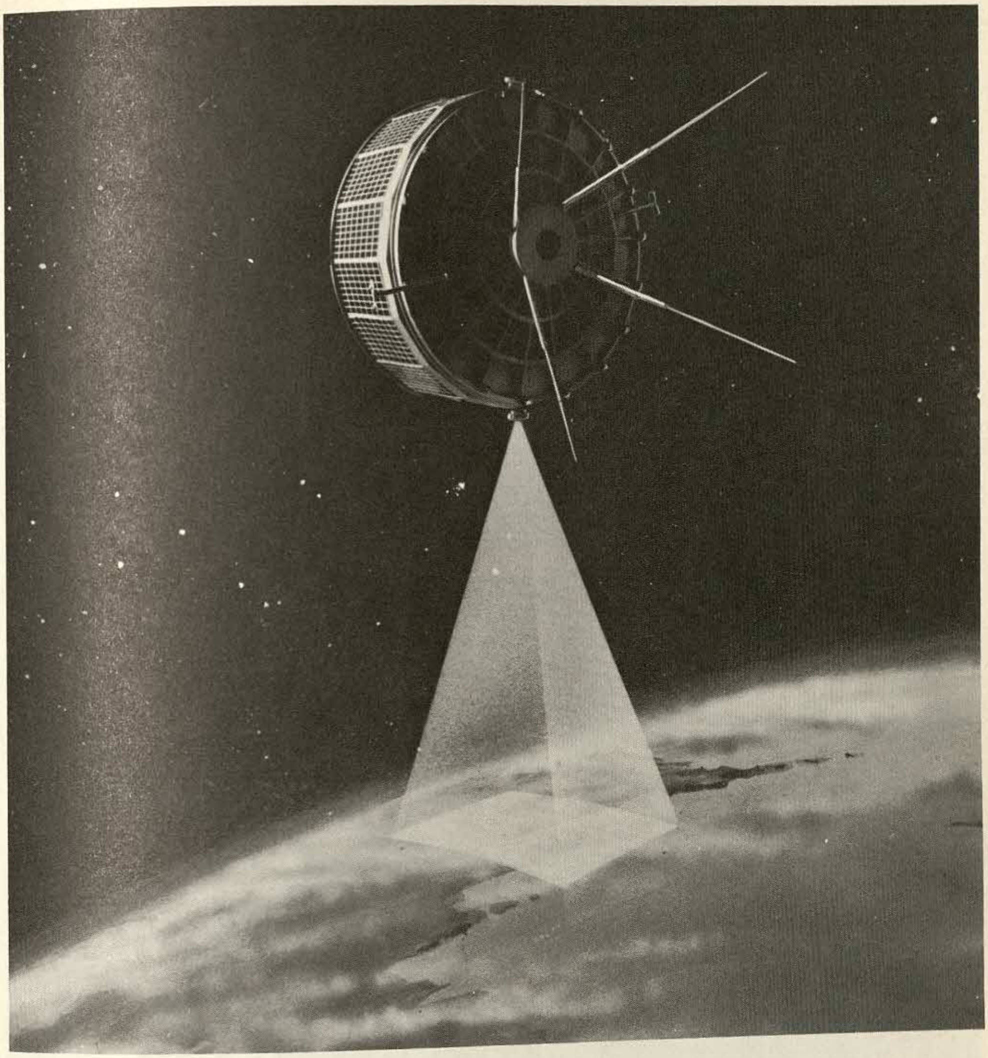
The use of radio telescopes has opened up a new field of study called radio astronomy. Radio telescopes are being used to explore the sun, planets, distant stars, and galaxies.

Satellites and Spacecraft

Throughout man's history there has been a steady increase in his knowledge of space. From earliest times to the present, instruments for space study have been invented and improved. The telescope, camera, and spectroscope, have provided us with much valuable but indirect information. But man and his instruments are at the bottom of an ocean of air. The dense blanket of air that surrounds the earth causes many problems in observing objects in the universe.

For centuries, man has dreamed of propelling himself away from the earth out into space itself. Not so very long ago, he succeeded. On October 4, 1957, the Space Age began. On that day the first man-made satellite, Sputnik I, was blasted into space.

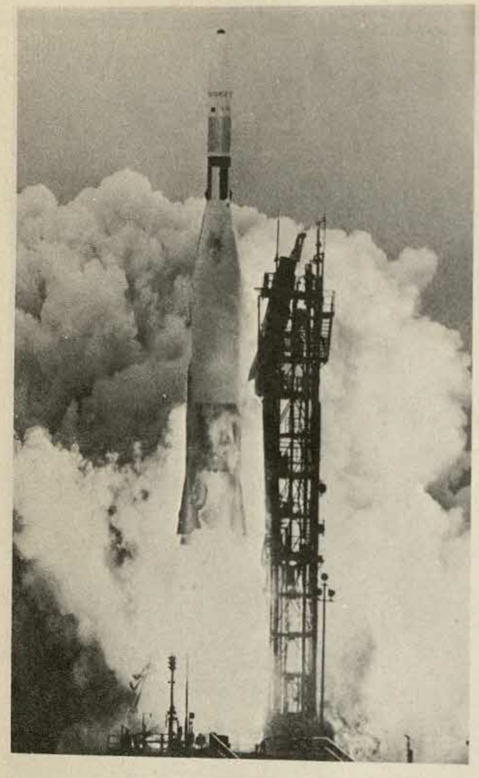




TIROS, a weather satellite

The earth has always had a natural satellite, the moon. Since 1957, man has sent many artificial satellites into orbit. Each satellite is packed with sensitive instruments to measure various conditions in space. What is the advantage of orbiting a telescope?

A great many satellites are orbiting the earth at this very moment. Most of them are invisible to the naked eye. But some of them reflect a great deal of light and can be seen easily. The information gathered by these man-made "moons" is paving the way for the development of space stations and spacecraft.

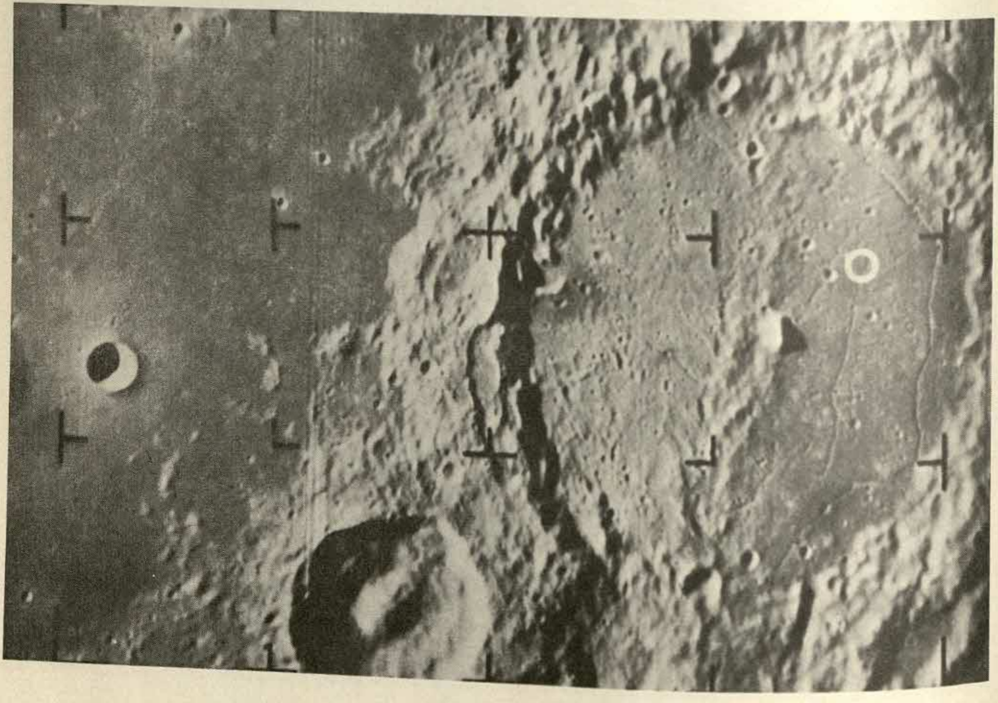


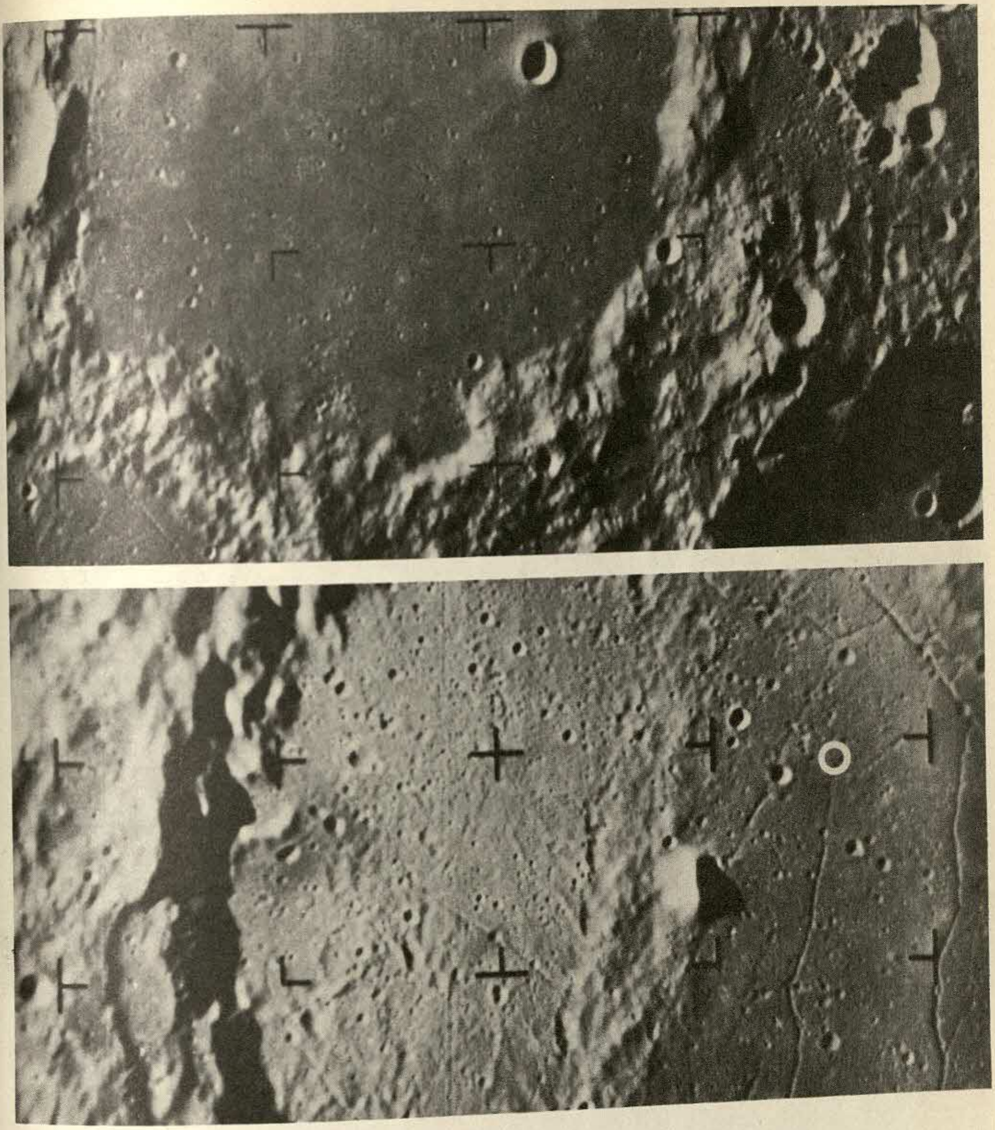
Ranger IX

Space explorers, the astronauts and cosmonauts, have already orbited the earth in space capsules. The United States hopes to land a man on the moon very soon. If you have been keeping up to date with your science reading in magazines and newspapers, the photographs will look familiar to you. What do the pictures show? Do you know how they were taken?

Look carefully at the picture of the spacecraft. What is its name and what work did it do for scientists in 1965?

Think of it! In a few short years man will be able to propel himself into space and set





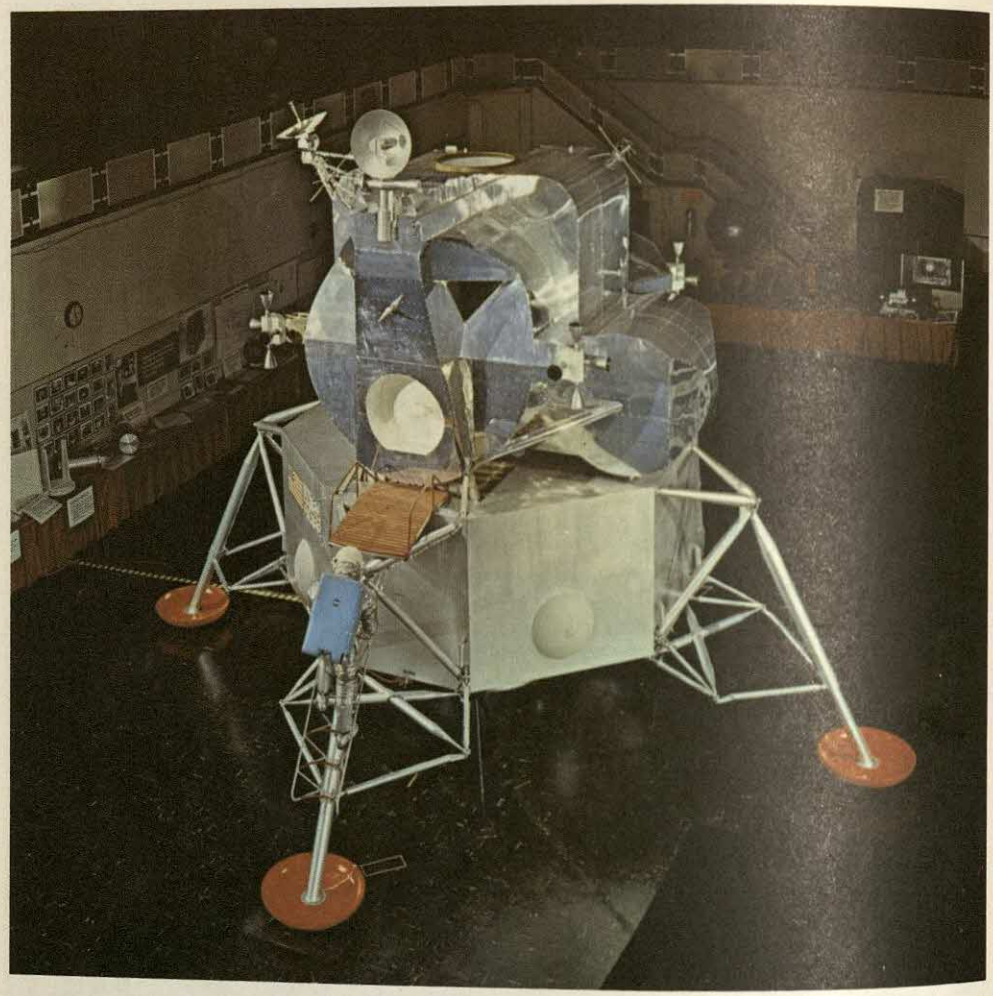
Photographs taken by Ranger IX

foot on places other than the earth.

We live in an exciting age. As old instruments are made more accurate and new instruments are developed, our knowledge of space and the objects in it grows. We find the answers to old questions and learn to ask new ones.

The Puzzle of Venus

The planet Venus has been called "a puzzle wrapped in clouds." How have scientists tried



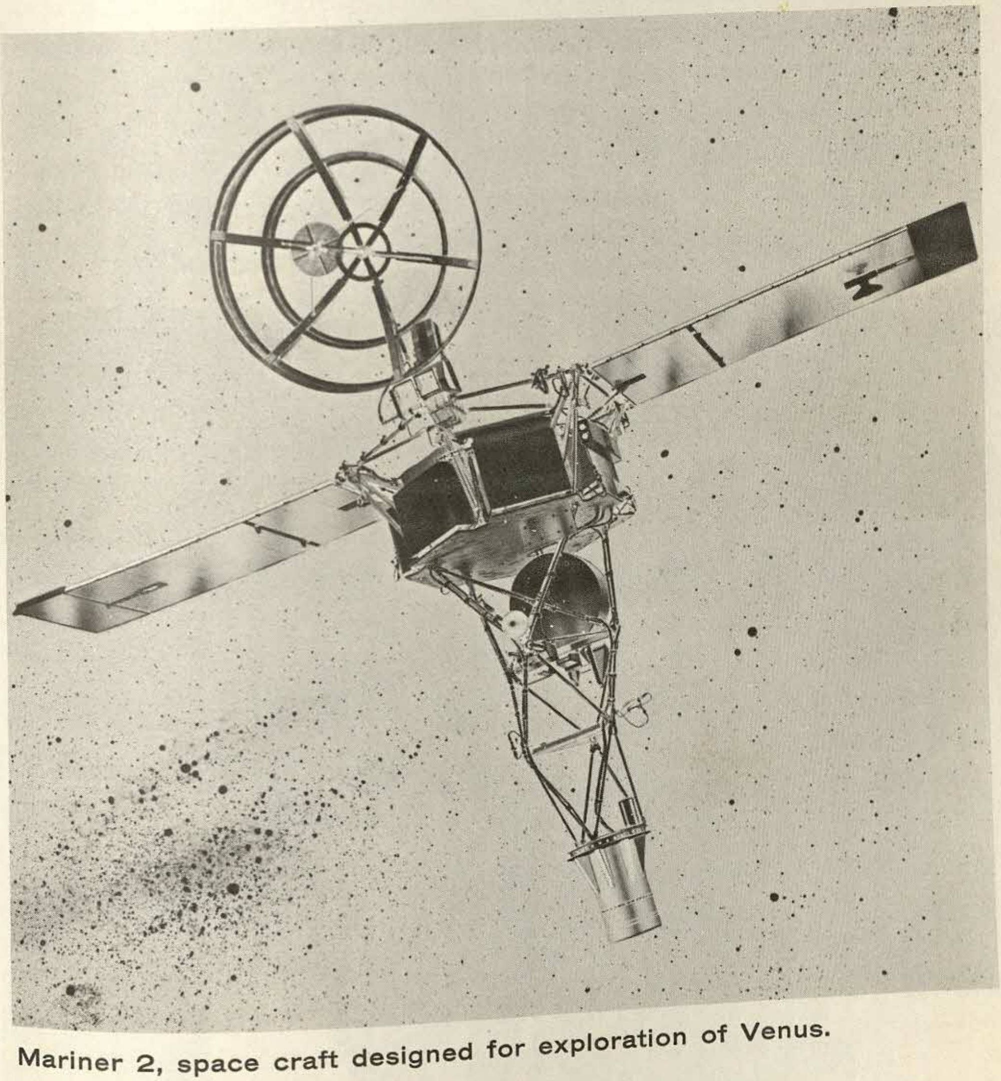
Model of the Lunar Exploration Module (LEM), being developed to land the first United States Astronauts on the moon.

to solve that puzzle? With the large telescopes they could tell that Venus was surrounded with very dense clouds. They reasoned that there must be plenty of water on Venus. They also knew that the temperature was high. This led them to believe that the surface of Venus was hot and steamy. However, the spectroscope showed very little water in the clouds of Venus.

If it is true there is very little water in its clouds, what else might the clouds be made of? Some scientists thought they must be dust. If the clouds were dust swirling around the planet, what do you think its surface would be like? Deep, hot, and wind-swept? That is what the scientists believed until the spectroscope showed that there is a great amount of carbon dioxide in the atmosphere of Venus.

Now they were faced with a new problem, how to explain the presence of so much carbon dioxide. According to one theory, all the oxygen was used up by chemicals composed of carbon and hydrogen. If this theory is true, then the surface might be covered with oil, and the clouds might be smog.

In 1956 it was discovered by scientists at a research laboratory that Venus is sending out radio

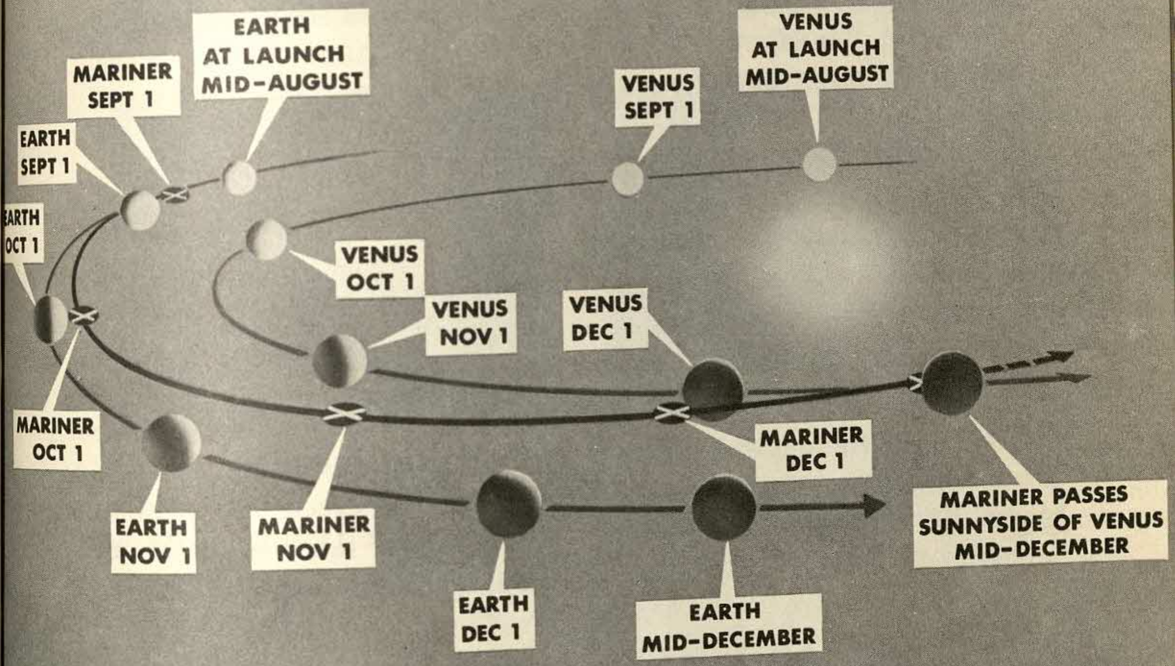


Mariner 2, space craft designed for exploration of Venus.

waves. Because of the kind of radio waves given off, it was thought that the temperature at the surface of the planet should be about 600° F. Several theories were suggested to explain the temperature of Venus.

Mariner II, an interplanetary space probe launched by NASA in April, 1962, passed very close to Venus on December 14, 1962. Its instruments recorded information about that planet and transmitted it back to the earth. Mariner II's instruments showed that the temperature at the surface of Venus was probably about 800° F., and the temperature at the base of the clouds about 200° F.

DISCOVER Paint the outside of a large juice can a dull black. Polish the outside of a second, large juice can. Put a thermometer through one hole in the top of each can. Cover the other holes with tape. Stand both cans about 10 inches from a hot electric iron. Read the temperature in each can. Read and record the temperatures every 30 seconds for about 4 minutes. To show your results, make a graph like the one shown. How do you explain your results? □□



Typical Mariner 2 Trajectory

Another part of the "puzzle" of Venus was its rate of rotation. Estimates ranged 20 days to 250 days. Scientists in the Soviet Union interpreted their results to show that Venus rotated once on its axis in fewer than 11 days. Scientists in the United States interpreted similar observations to show that the period of rotation of Venus was about 225 days. Mariner II's instruments seemed to show that Venus rotated very slowly. Astronomers continued to investigate the problem.

In 1964, it was announced that Venus rotates backward. Radar studies made at several observatories led to this conclusion. Most of the bodies in the solar system rotate counter-clockwise. Venus rotates clockwise, completing a rotation every 247 days. If you were on Venus, you would see the sun rise in the west and set in the east.

With such a slow rate of rotation, one day on Venus is as long as 118 days on earth. Yet Mariner II did not detect any great difference in temperature between the day side and night side of the planet. How do you think the heat from the day side might get to the night side of Venus? Might the cloud layer trap heat on the night side?

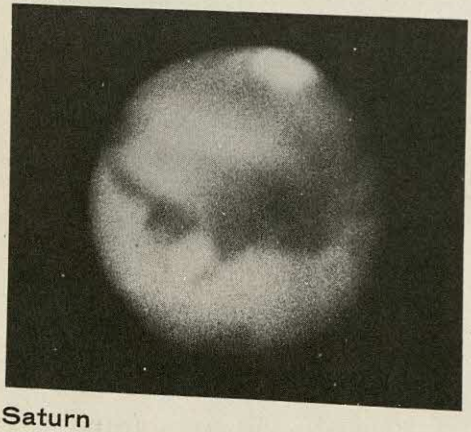
Radar reflections from Venus seem to indicate that the surface may be sandy. If that is so, can you picture the great sandstorms there may be on Venus? Although modern instruments and space probes help us to answer some of the questions about Venus, this planet is still somewhat of a "puzzle wrapped in clouds."

Life on Mars?

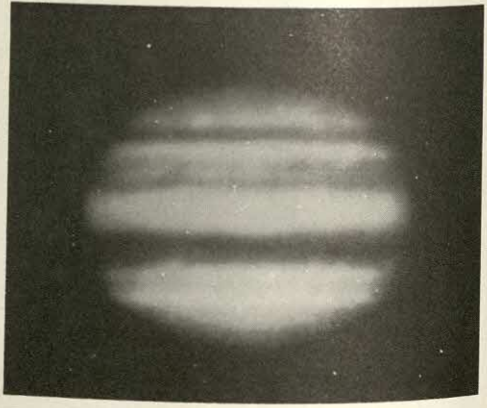
Mars is another mystery. Is there life on Mars? What are the so-called canals? How can we account for the white cap on Mars? What are the green markings?

There are theories about all these features, but no positive

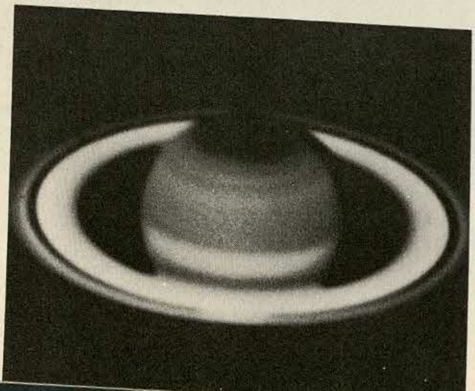
Mars



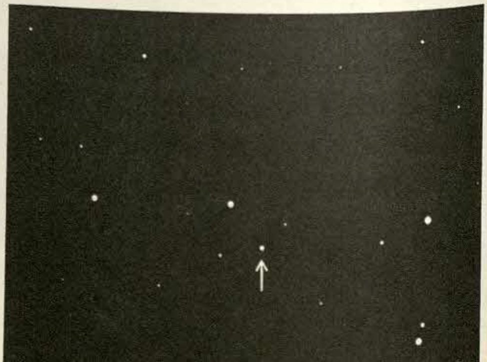
Jupiter

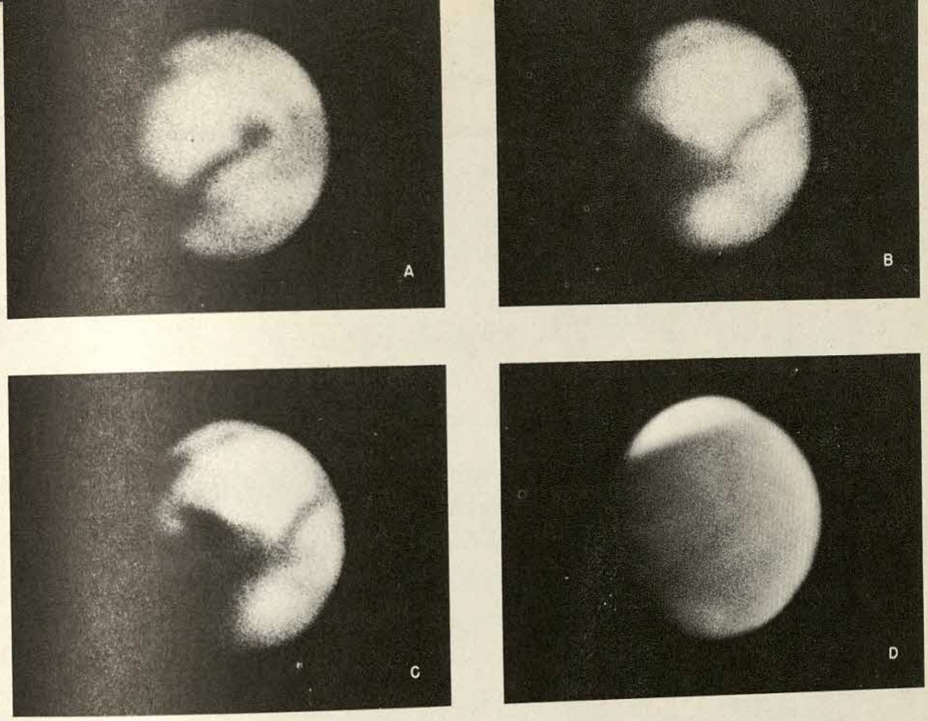


Saturn



Pluto





Views of Mars

answers as yet. For example, studies with the spectroscope recently showed that there are compounds on Mars that are like the hydrogen and carbon compounds on earth. These compounds are essential to most life as we know it here on earth. But whether or not these materials are helping to support life on Mars is still a mystery.

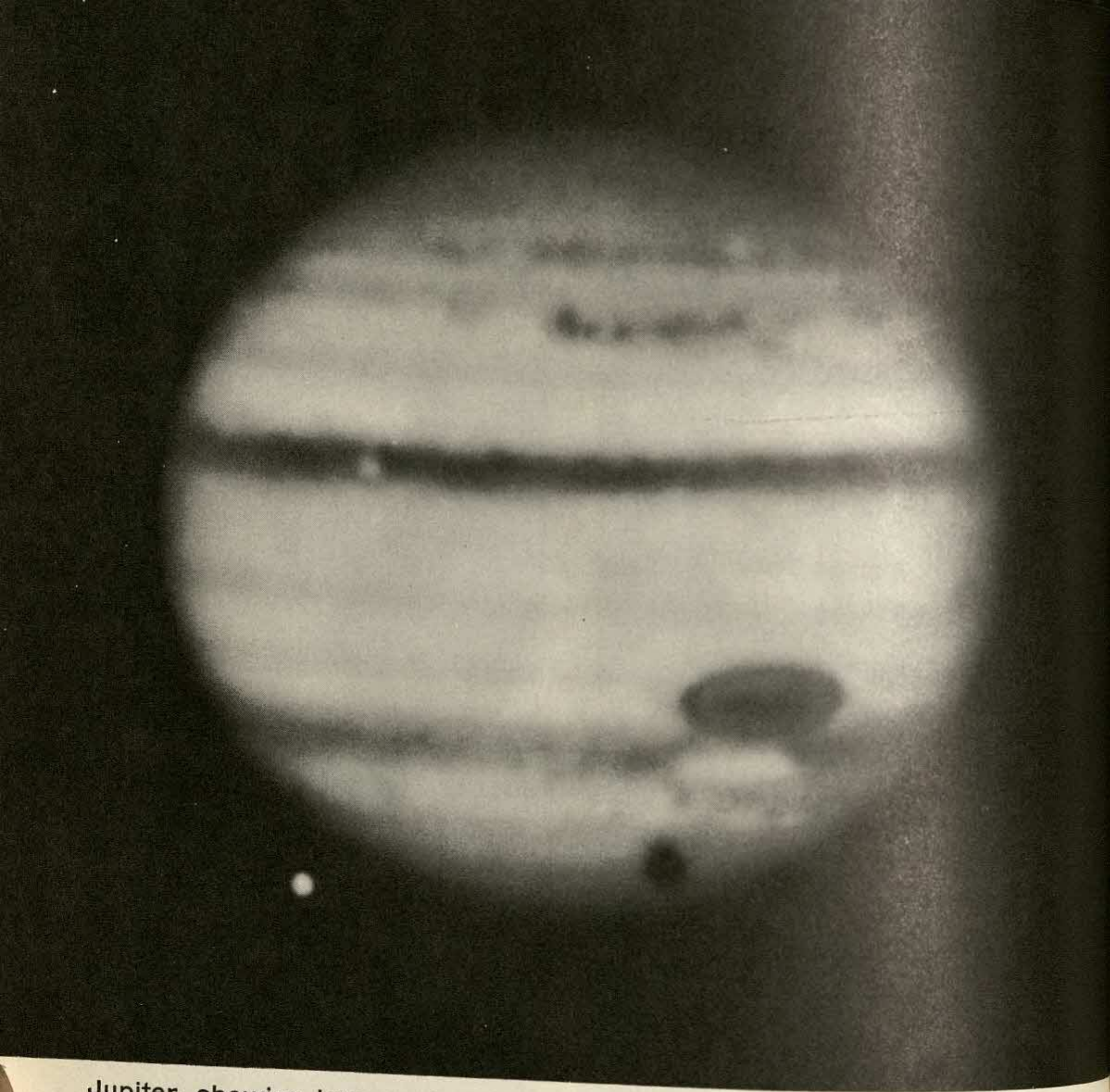
In November, 1964, the National Aeronautics and Space Administration launched Mariner IV to fly by Mars. Mariner IV was equipped to send television pictures of the surface of Mars. Study of these pictures, and further probes, may answer some of our questions about this planet.

Jupiter, Mysterious Giant

Jupiter has been called a "mysterious giant." Do you know why it is called a "giant"? How many times greater is the diameter of this planet than the diameter of the earth?

Jupiter has many interesting surface features. Its Red Spot and colored bands can be seen easily with a small telescope. The bands are not always the same color. They vary from brown to green to yellow.

The Great Red Spot has been observed since astronomers began watching Jupiter with telescopes. Sometimes it is a dull pink; sometimes it is a dull red. No one knows what causes the Spot or



Jupiter, showing large red spot

what it is. Some think it is a solid body floating in the atmosphere. Others think the Spot is a column of the atmosphere swirling around some structure on the solid surface of the planet.

In 1955 it was discovered that Jupiter gives off radio signals. The origin of these signals has not been completely determined as yet. It is also known that Jupiter has a strong magnetic field surrounding it. Perhaps this field is in some way responsible for the radio signals.

There is still much to be learned about the giant planet. Radio telescopes and space probes may help to unlock many of Jupiter's secrets.

THINK

Air and other gases are poor conductors of heat. What reasons might you give for this fact?

If you observed that there were no clouds in the stratosphere, what reasons could you give that might cause this to happen?

Two scientists took a balloon to about 70,000 feet above sea level. When the balloon descended and landed, the scientists were dead. What might be the explanation?

Two boys take two plungers, wet them and place them together, pushing out all the air. They then try to pull the plungers apart and find they cannot. What explanation can you give?

If the air at the base of a mountain has the temperature of 80° F. and it rises up the side of a mountain and begins to form a cloud at 5,000 feet, what is the dew point of the air? (Scientists know that air cools at the rate of 5½° F. per 1000 feet.)

Write a story tracing the route of water from its original source to your faucet.

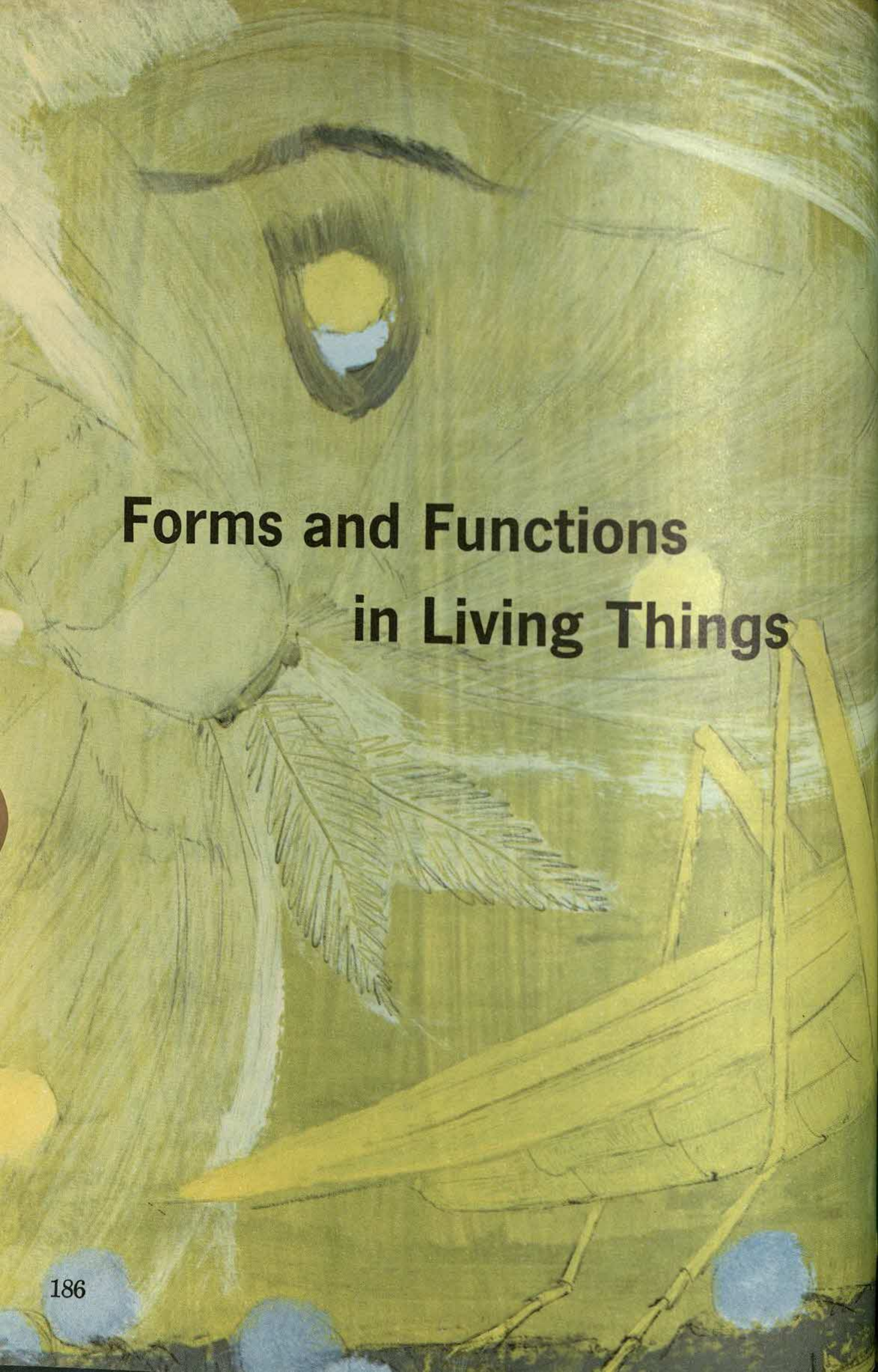
Rocket travel is coming closer to reality. Describe the difficulties one might have if rockets traveled at a height of 80,000 feet. Base your answers upon what you know about air and water.

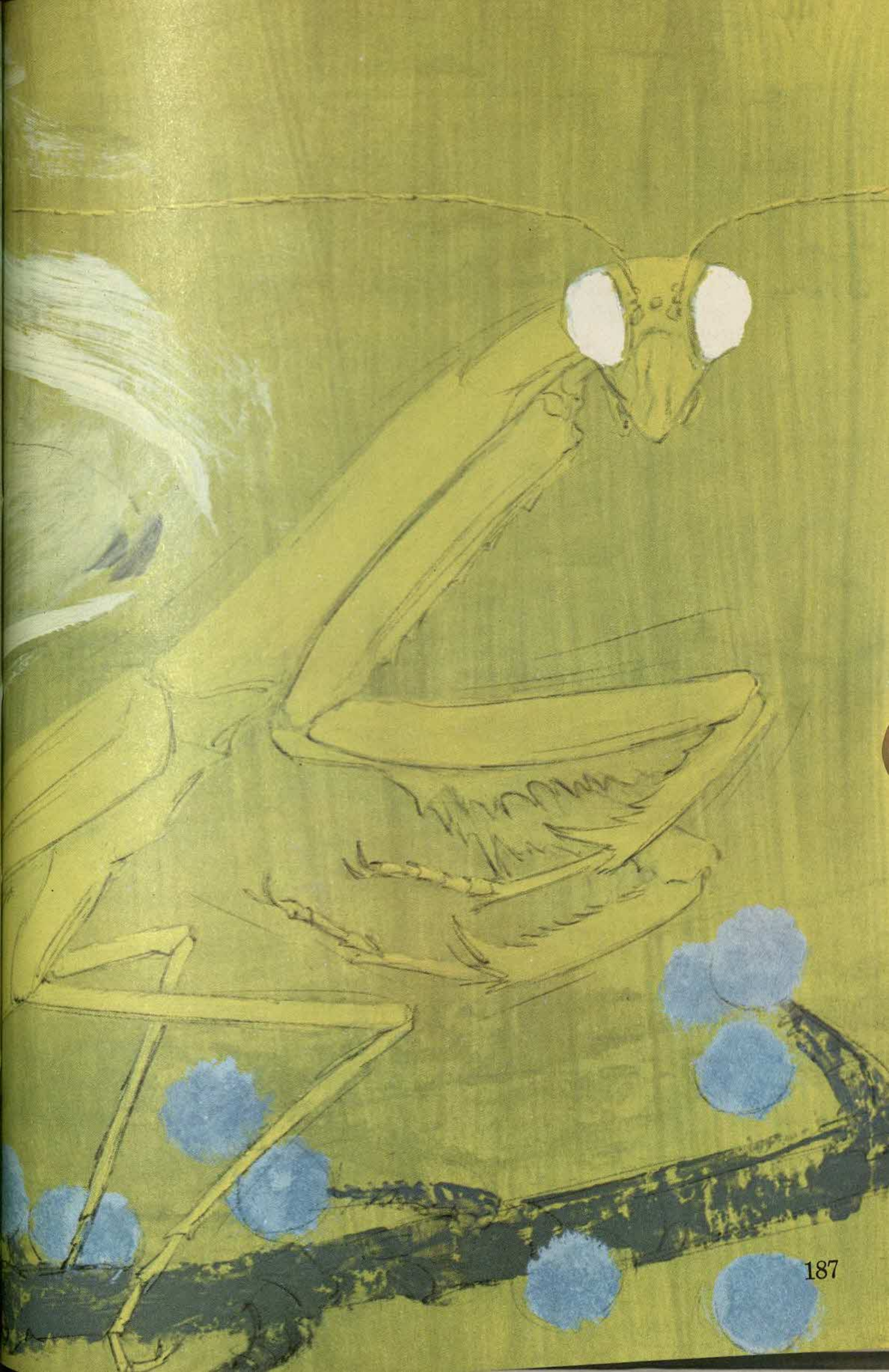
The movement of air masses over the ocean are much easier to follow than over the land. How can you explain this?

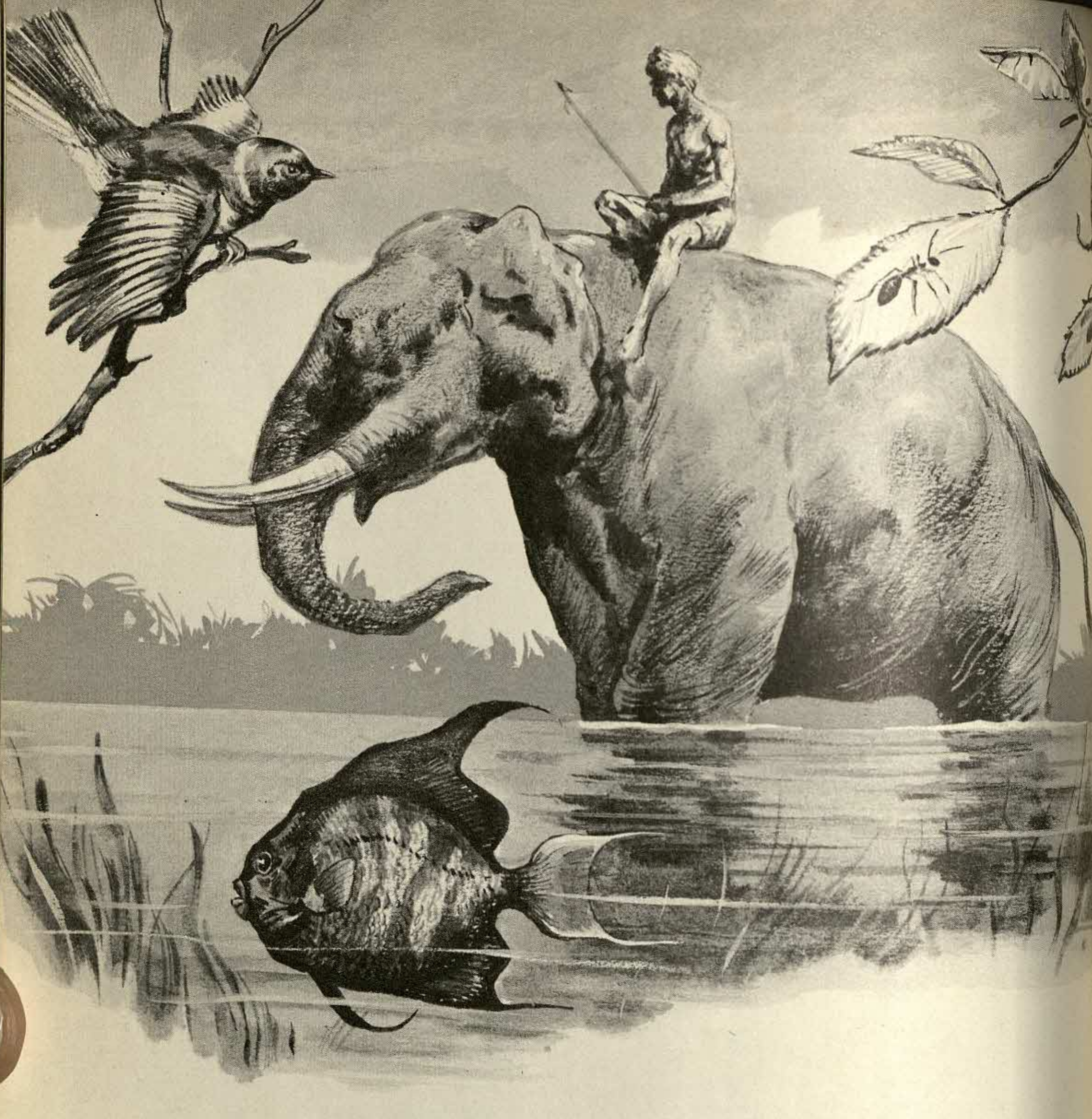
PROJECT

Construct a mural showing how man has progressed in exploring the oceans of air and water and space. Show how scientists have solved the following problems: lack of oxygen, extreme temperature, and extreme pressure.

Forms and Functions in Living Things







Life Requires Organization

Buildings, machines, and other things made by man require some kind of organization. An architect makes special designs for grocery stores, homes, banks, and theaters because each building serves a different purpose. Why is your home made up of different parts? Why does it have a roof, windows, and beds?

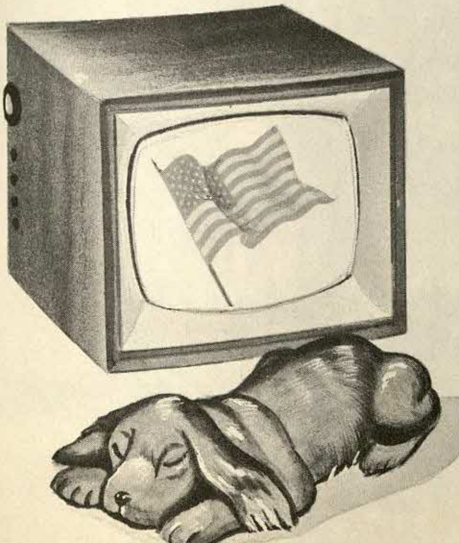
Are living things organized? Why is an ant so small and an elephant so large? Why is a fish shaped the way it is? Why does a bird have legs, wings, and a beak? The size and shape of a living thing enable it to carry on its life activities.

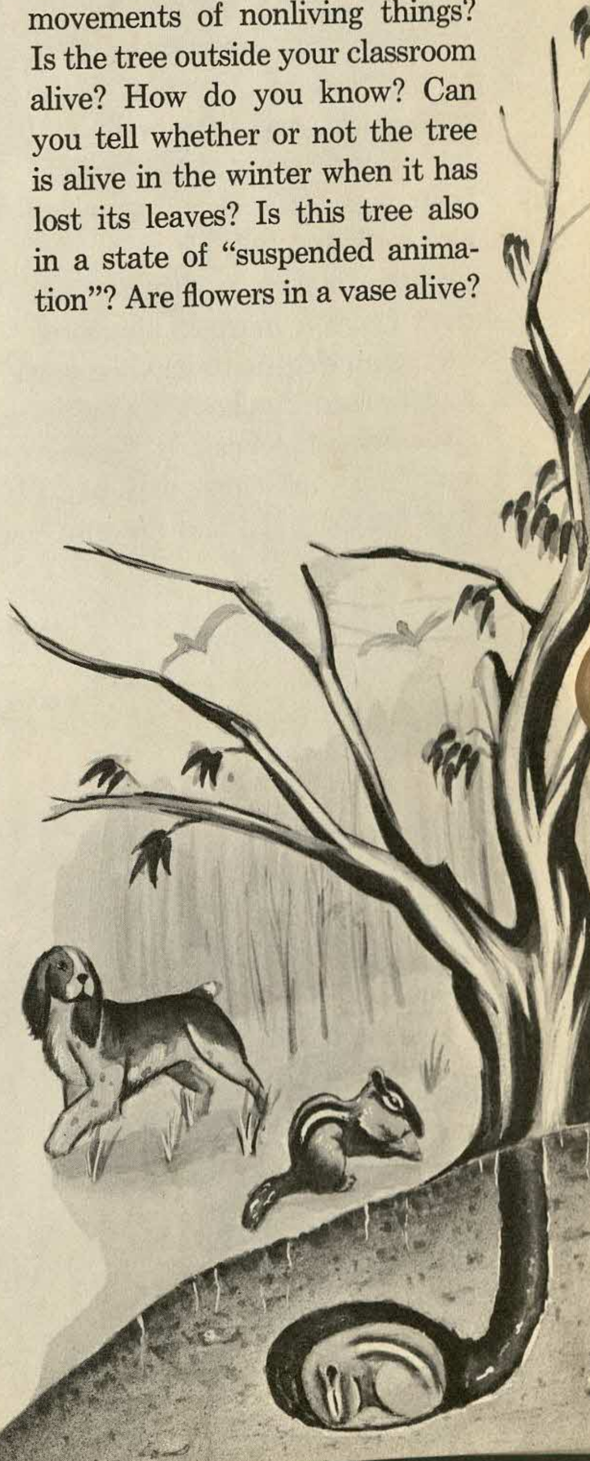
Living and Nonliving Things

How can you tell that an animal is alive? Is a sleeping dog alive? How do you know?

Chipmunks are bright-eyed, little ground squirrels with striped coats of rusty red. During part of the cold winter months when little food is available, they fall into a kind of sleeping state called hibernation (*hy*-ber-NAY-shun). If you could find a hibernating chipmunk curled up like a kitten in the sleeping apartment of its burrow, you might pick it up without arousing it. The chipmunk would feel cold; its heart beat and breathing would be very slow. Scientists call this condition "suspended animation." Is such a chipmunk alive? How do you know?

What living things do you see in the picture? Give reasons for your answers. Can you tell that a thing is alive by the way it moves? How do the movements of living things differ from the movements of nonliving things? Is the tree outside your classroom alive? How do you know? Can you tell whether or not the tree is alive in the winter when it has lost its leaves? Is this tree also in a state of "suspended animation"? Are flowers in a vase alive?



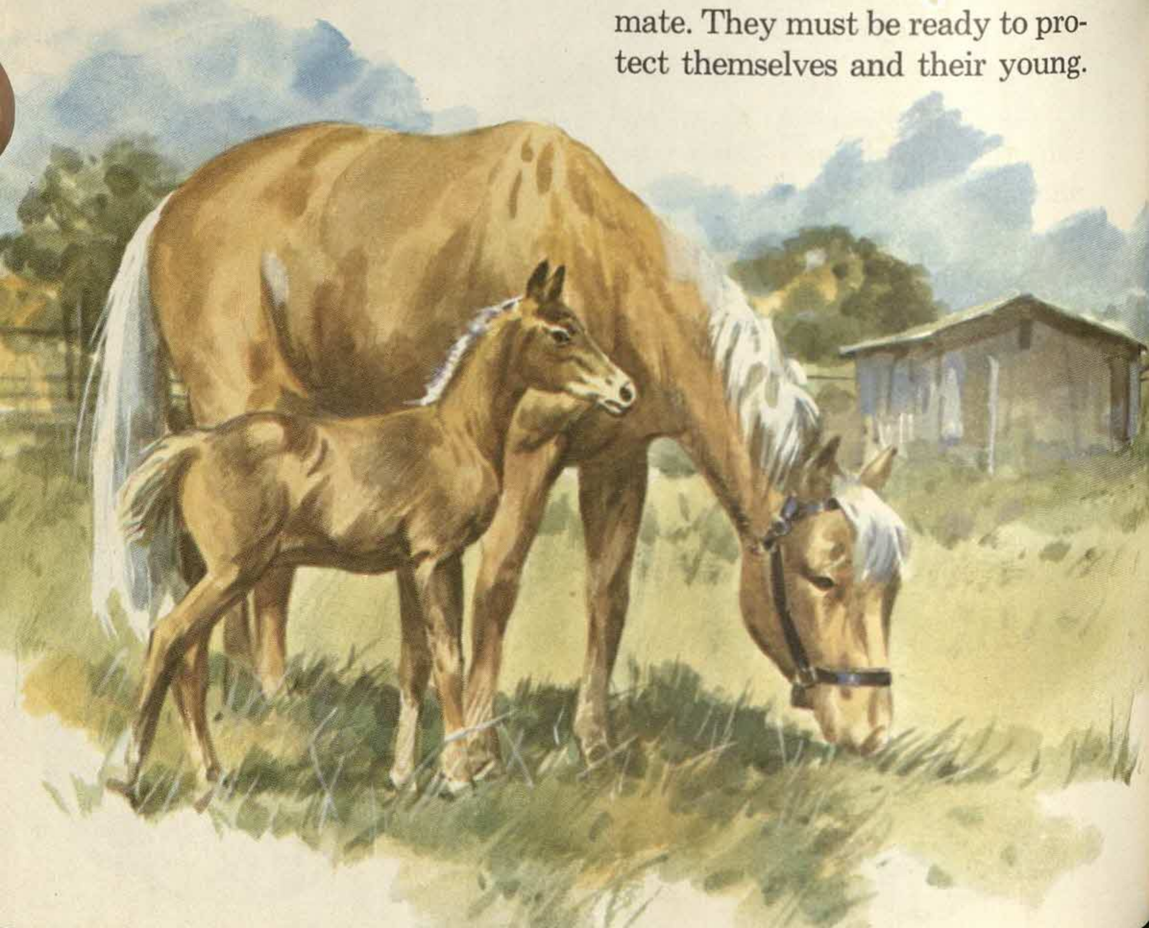


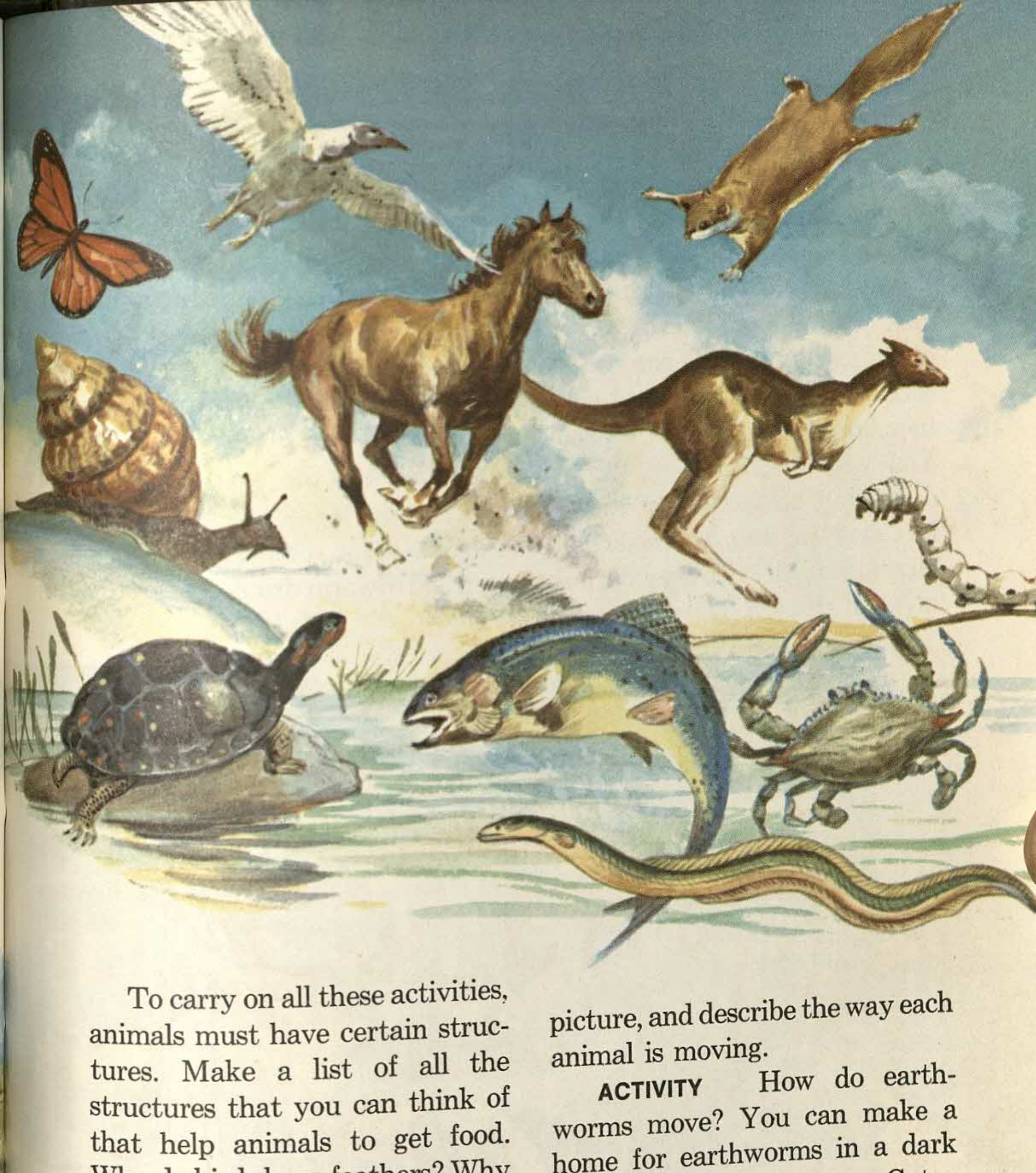
Write down as many characteristics of living things as you can. Then list the things machines can do. How can you tell that something belongs to the group of living things rather than to the class of machines? Some mechanical dolls can walk and talk. How does such a doll differ from your little sister, who can also walk and talk?

What makes an electric train run? Do you move in the same way as an electric train when you walk or run? You know that a fire gives light and heat. It "grows" and "eats up" wood and paper that are fed to it. Is a fire alive?

Animals Are Built to Fit Their Needs

Living things grow. Animals sometimes change in form as they grow. As a tadpole grows, how does its form change? Living things eat food or get nourishment in some way. Mature animals can produce young like themselves. When a living thing produces another living thing like itself, the process is called reproduction. Dogs have puppies, chicken eggs hatch into baby chicks, and frog eggs hatch into tadpoles. Animals must move about to find food and to seek a mate. They must be ready to protect themselves and their young.





To carry on all these activities, animals must have certain structures. Make a list of all the structures that you can think of that help animals to get food. Why do birds have feathers? Why do cows have horns? Why do chickens have gizzards? Why do tadpoles have tails?

How Animals Move

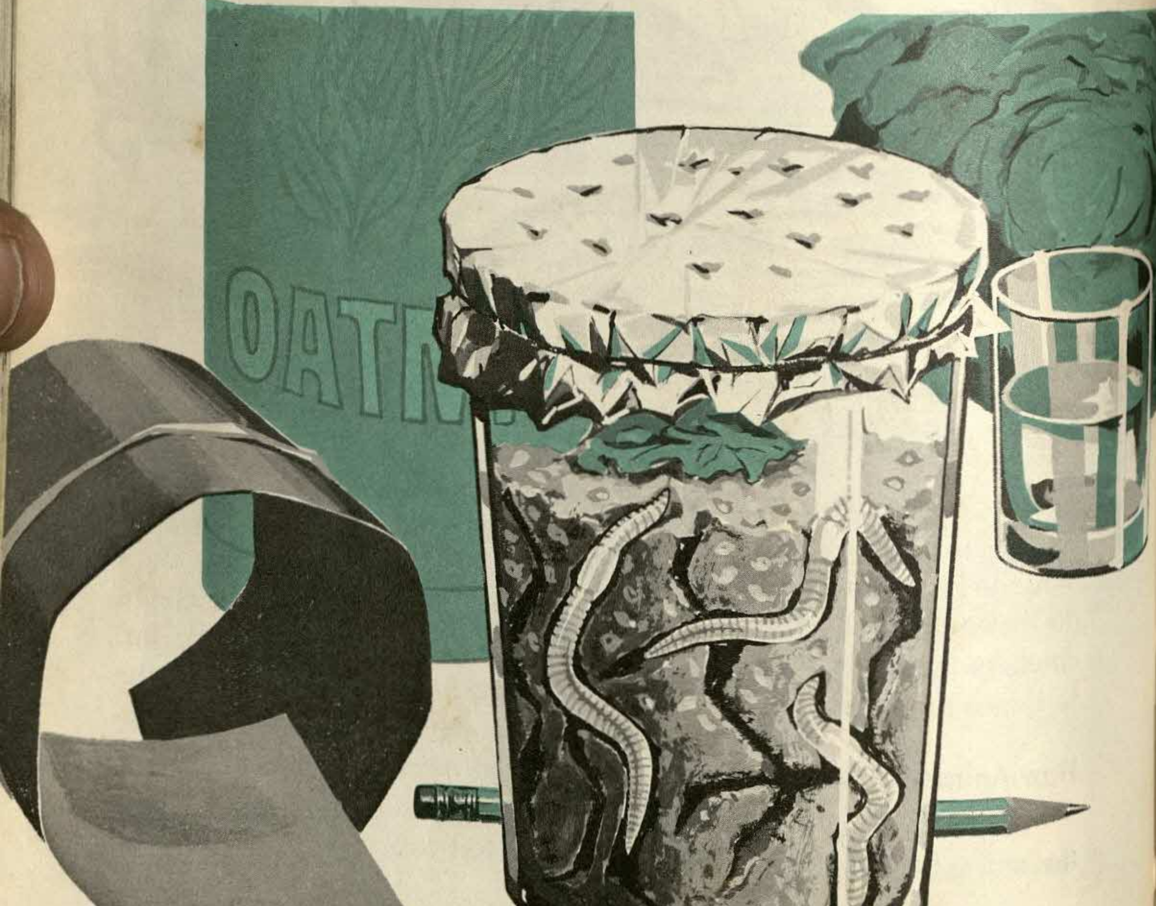
In how many different ways do animals move? Look at the picture, and describe the way each animal is moving.

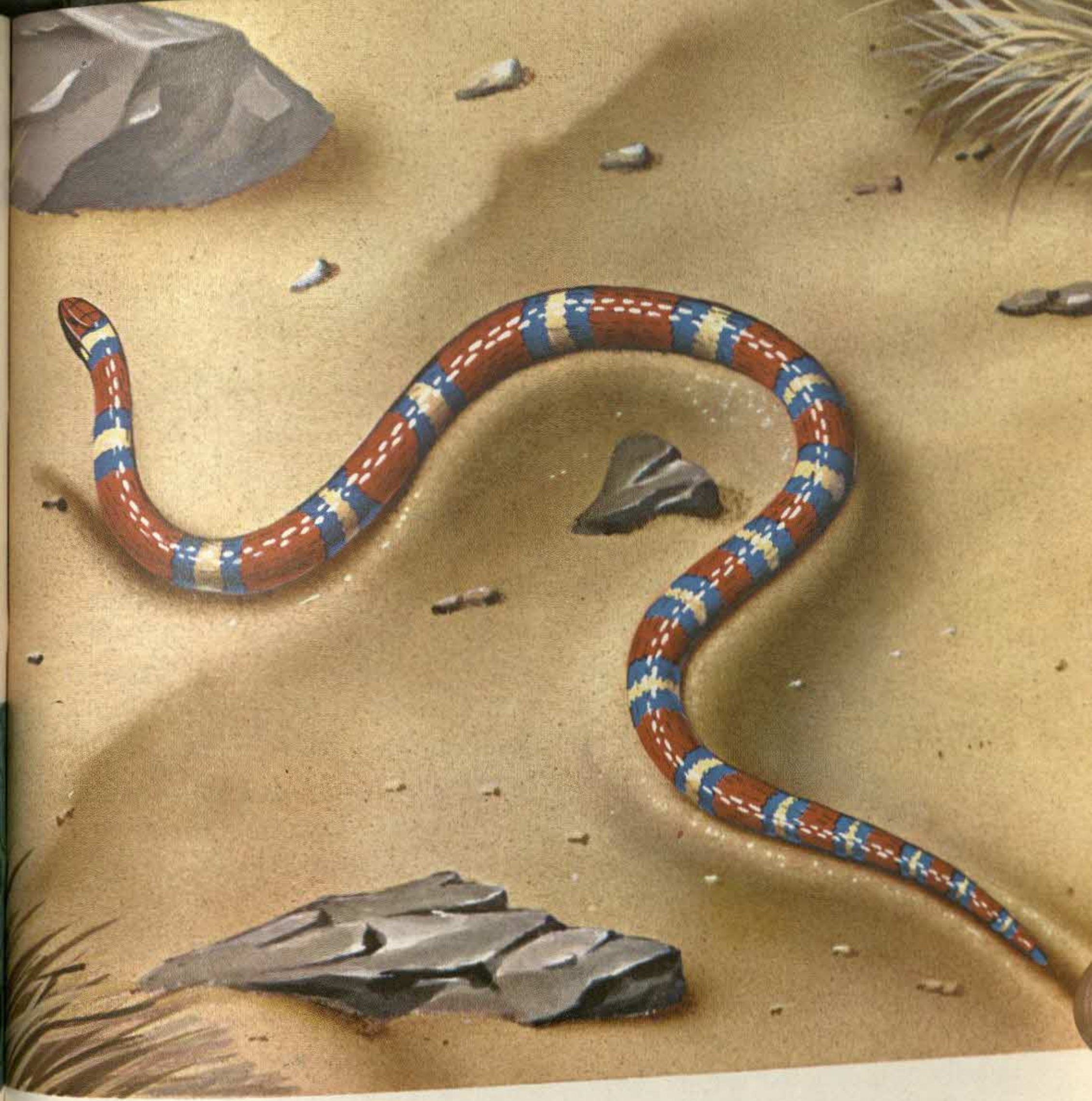
ACTIVITY How do earthworms move? You can make a home for earthworms in a dark corner of your classroom. Get a large beaker or wide-mouth jar, enough dark fertile soil to fill the jar, about 4 tablespoons of uncooked oatmeal, 2 lettuce leaves, water, a pencil, a piece of aluminum foil to cover the jar, a sheet of black paper, and about 5 earthworms.

Put half of the soil in the jar—do not pack it down—and place the earthworms on the soil. Mix the rest of the soil with the oatmeal, and put the mixture on top of the earthworms. Tear the lettuce into small pieces. Put the lettuce on the soil. Moisten the soil. You will have to keep the soil damp, but be careful not to flood it. Cover the top of the jar with aluminum foil. With a pencil, poke holes in the foil. Cover the sides of the jar with a sheet of black paper. Why is this necessary? Twice a week put bits of lettuce and damp oatmeal on the soil. Keep a list of your observations.

Place an earthworm on a piece of damp paper and watch it crawl. Describe its movements. Turn the earthworm on it back. What happens?

Pick up the earthworm and feel along its underside. Have you ever seen a robin trying to pull an earthworm from the ground?

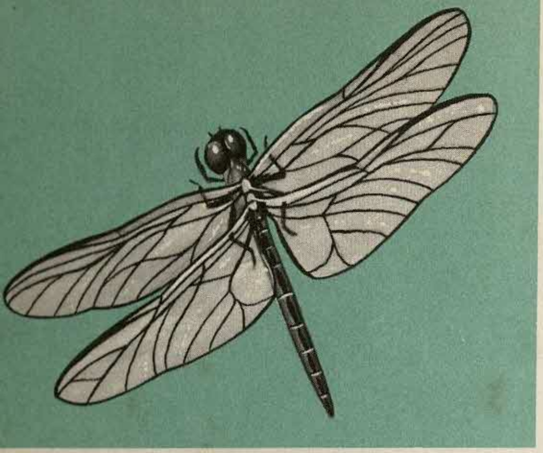


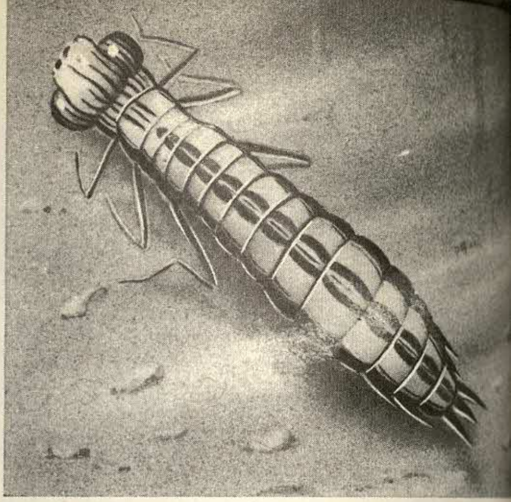


What structure helps the earthworm cling to its burrow? □□

You could find out how a snake moves if you could watch one crawl over sand. A pile of sand is raised by each curve in the snake's body. The snake moves forward by pushing against these piles. If you put a snake on a piece of greased glass, it will make the usual movements, but will not get anywhere. Why?

Sometimes a snake moves in a straight line, like a caterpillar. If you are fortunate enough to see a snake moving in this way, watch the lower side of its body. Can you see any movement of the scales on the underside? Some snakes can even climb trees.





COLLECT Young dragonflies live in the water and are called nymphs. Collect some dragonfly nymphs from a pond. Look for them among water plants or in the mud at the bottom of the pond, where the nymphs lie in wait for their prey. Place the nymphs in an aquarium in which the water is not very deep. Feed the nymphs small pieces of meat or small, soft-bodied insects. Nymphs have big appetites. Do not put them with other small animals you want to keep alive.

Usually the nymph moves slowly through the water; it depends on the quick action of its lower lip to catch its prey. At times, however, the nymph can move very quickly. It draws water into an opening in the rear of its abdomen, and shoots the water out in one direction. The nymph itself moves rapidly in the opposite direction. How is this type of motion similar to that of jet airplanes? ☐☐

Animals that move swiftly and easily need a good support for their bodies. Have you ever seen a workman build a house? One of the first parts to go up is the framework. Why is the framework necessary? Our bodies have a framework covered by flesh, muscles, and skin. Do you know what this framework of ours is called? Many animals, other than man, have skeletons. Only animals that live in very moist places or in water where they can slide along or float can get along without skeletons.

Animals with skeletons like yours inside their bodies are called vertebrates (VUR-tuh-brates). The name vertebrate comes from the word vertebrae, meaning the bones which make up the backbone. Vertebrates have a skeleton inside their bodies, called an internal skeleton. How many vertebrates do you see in the pic-

ture? Make a list of vertebrates, and describe the different ways they move.

The five big groups of animals with backbones are fishes, amphibians, reptiles, birds, and mammals. Do the animals in each group have a distinctive way of moving? You know that fishes have fins for swimming, and birds need wings to fly. Many reptiles, like snakes, crawl; others, like lizards, run. Frogs, toads, and mudpuppies are amphibians. Do amphibians jump, run, or swim? Dogs, elephants, and man are mammals. How does the skeleton help all of these animals move?

Instead of an internal skeleton, some animals have a protective cover on the outside of their bodies. Animals which have this outer protective cover, or exoskeleton, are called invertebrates (in-VUR-tuh-brates). Their muscles are attached to the exoskeleton. Insects, crayfish, and clams are some of the animals that have exoskeletons. How many invertebrates do you see in the picture? Soft animals that have no skeleton must live in the water or in very damp places. Where does a jellyfish live? Where does a starfish live? How do these animals move? Name as many invertebrates as you can. Tell how they move about.

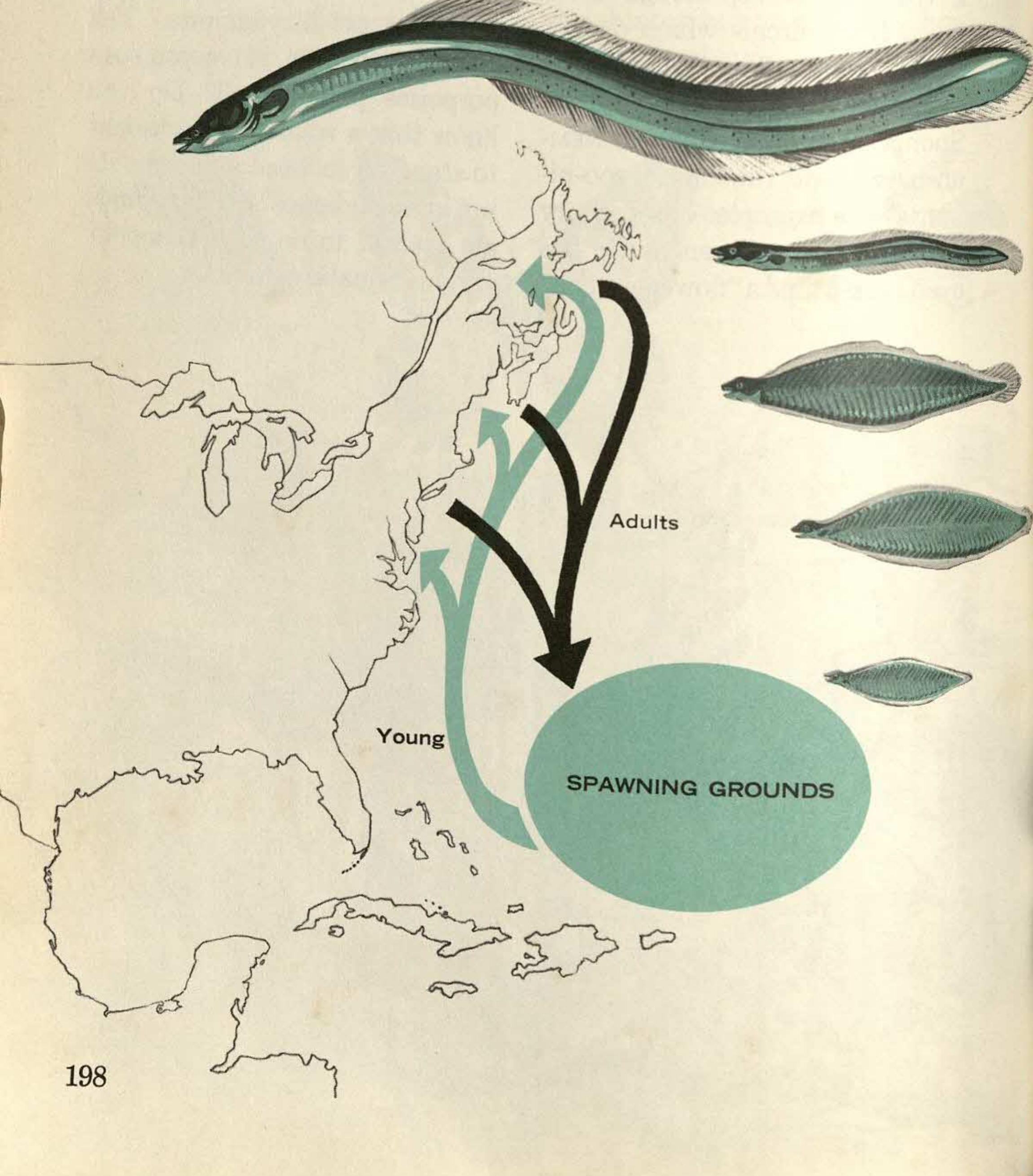
Animal Activity Differs from Plant Activity

If you were asked what an animal can do that a plant cannot do, you would probably reply that an animal can move from place to place, while a plant remains anchored in the soil. This is true, of course, though there are a few animals which do not move about. They are called sedentary (SED-'n-te-ree) animals. Sponges, sea anemones (uh-NEM-uh-neez), and tunicates (TOO-ni-kuhts) are examples of sedentary animals. The sea anemone has even been called a "flower animal."

Besides moving from place to place, animals can do something else that no plant can do. A trained Irish setter can locate quail for a hunter; a rosebush, of course, could never be trained to do such a thing. Animals can learn to perform tricks and do jobs for man. Have you ever trained a pet of your own? Tell the class about it. Have you seen porpoises playing ball? Do you know that a whale can be taught to stand on its head and wave its tail at an audience? Sea mammals are trained to do such things at various aquatic exhibits.

There are also many remarkable actions that animals perform without being taught. Does the mother spider teach her young to spin a web? Who teaches the worker ant to gather up the pupae and larvae, and carry them out side the nest when danger threatens?

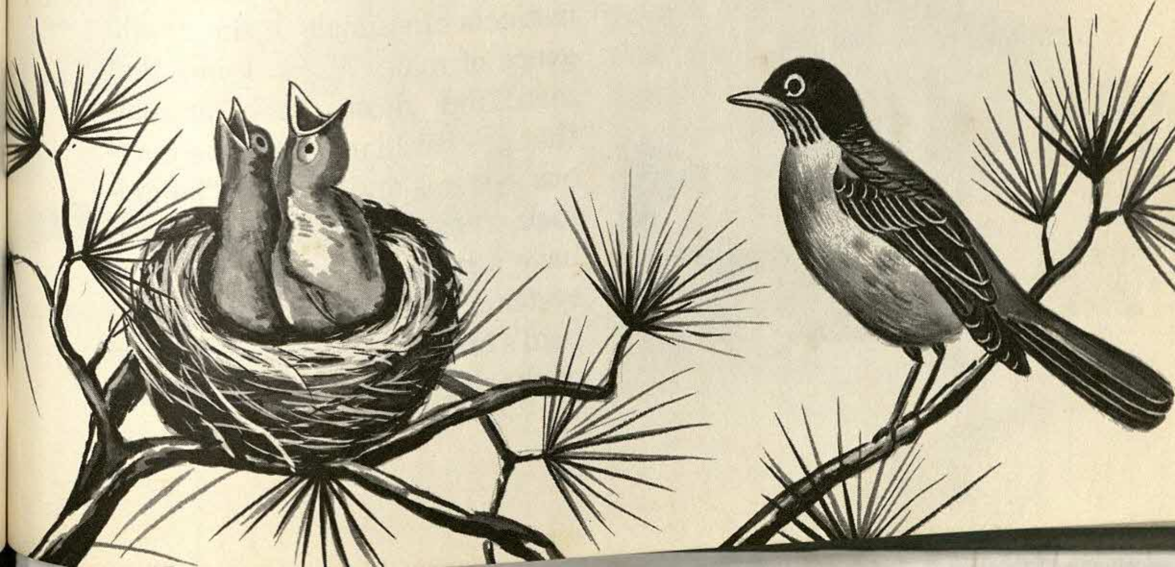
In the autumn, American eels go from their freshwater homes into the mid-Atlantic to spawn. Then both parents die. They cannot show the young eels back to the fresh waters. The young eel larvae begin a long journey through the ocean. In about a



year, these tiny bits of life reach inland fresh water like that from which the parent eels came.

What makes the eels return to fresh water? Do you remember why birds migrate at certain times of the year? These movements can be accounted for by a special power in animals which we call "instinct."

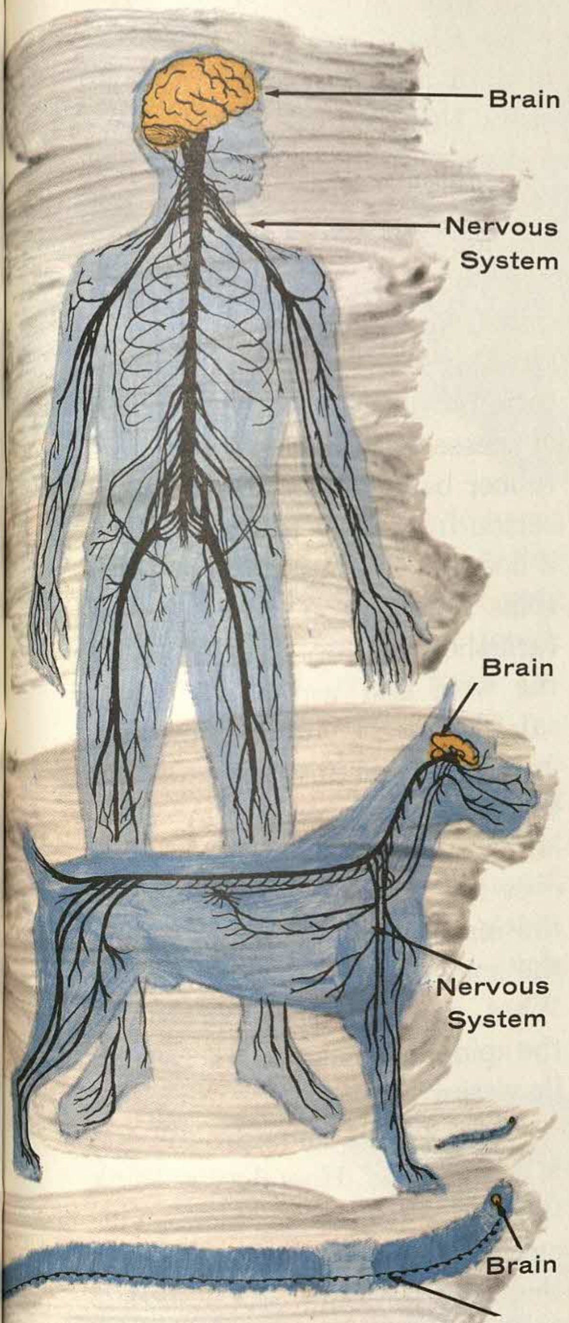
How does instinct differ from man's intelligence? Collect two abandoned robins' nests from two different places. Notice how similar the nests are. Both are constructed of a bowl of mud and sticks, and lined with grass and threads of various kinds. The small sticks on the outside help to conceal the nest from cats and other enemies of the robin. If you were to collect many more robin nests you would notice that they are all made in the same way. Why do robins always build the same kind of nest?



Do all men live in the same kind of house? Compare the typical home of a Swiss mountaineer, an Eskimo, and an African, and you will find that people build homes to suit the needs of their occupation and climate. On the other hand, a comparison of robins' nests found in different cities, countries, or climates would show them all to be very much the same. How does man's intelligence differ from the animal's instinct?

When animals and men move from place to place, learn to do things, or act from instinct, their activity is more complex than the activity of plants. Plants respond to water, sun, heat, and cold, but plants do not *ask* you to give them water. They remain rooted in the soil, and in time of drought are quite helpless. What does a puppy do to let you know it is thirsty?

We do not fully understand instincts of animals or the intelligence of man. We do know that man and most other animals that are familiar to us have nervous systems and brains. The animals that can learn the most have a highly developed nervous system. Compare the picture of man's brain and nerves with those of the dog. The earthworm has a



very simple brain, and can be taught very little. Worms have been taught to run a maze, but the maze must be very simple. Can you guess why? Look at the size of the earthworm's brain.

How Animals Get Their Food

Have you ever seen a chicken suck a lollipop? Would you expect snakes to sit down and eat a bowl of ice cream? Does a giraffe walk into a grocery store to buy its supply of food for the week? Animals take foods that they are equipped to capture. They must live where they can find such food. Most animals have special structures—claws, tongue, teeth, horns, wings—for securing the particular foods they eat.

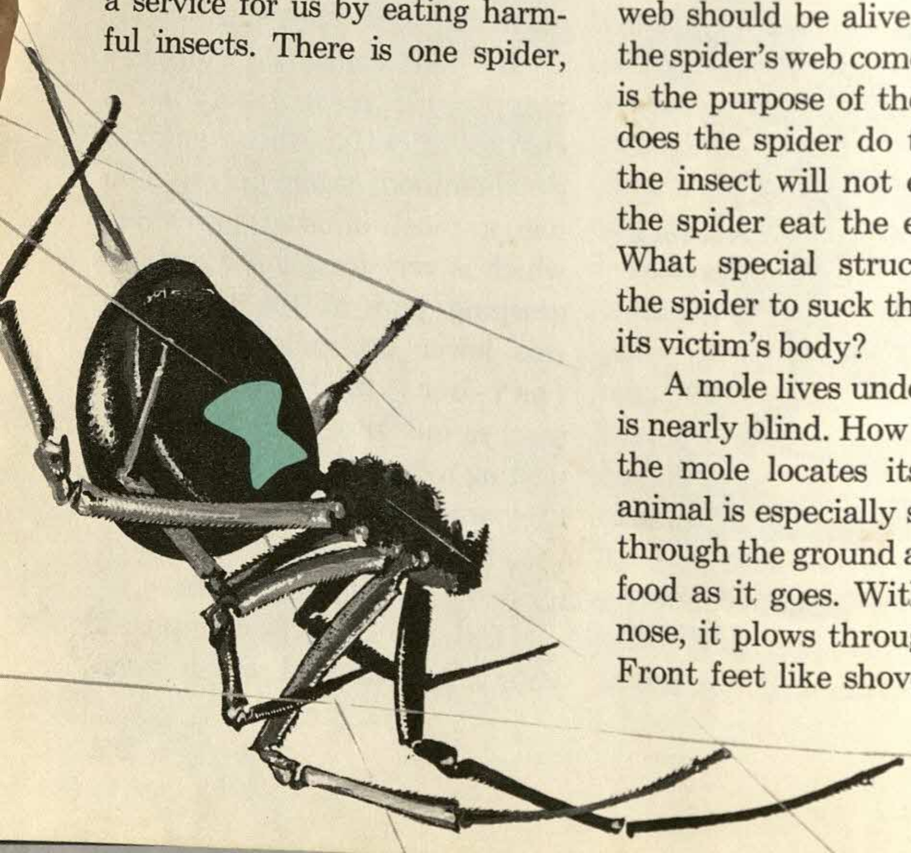
If you collected dragonfly nymphs, you have already had a chance to watch these animals get their food. A dragonfly nymph has a most unusual lower lip, which is very long and has sharp grasping jaws at the tip. With this lower lip, called a labium (LAY-bee-yum), the nymph reaches out and grabs an unsuspecting mosquito wiggler or other tiny water creature. When not in use, the labium folds up like a mask over the nymph's face.

You can keep the nymphs in your aquarium and watch them grow into adult dragonflies. Place a rock in the aquarium large enough for the dragonflies to climb upon after they become adults. When you release the adults outdoors, watch the way they fly. Dragonflies capture their food in the air, and sometimes even eat while flying. Their wings are attached to strong flight muscles. They zoom through the air very rapidly, catching flies and mosquitoes. Do you know any other animals that catch their food on the wing? Find out about the eating habits of the least flycatcher, and explain how this bird gets its name.

Most spiders are not harmful to man–in fact, spiders perform a service for us by eating harmful insects. There is one spider, however, whose bite can be very dangerous. This spider, the black widow, is found mainly in the western and southwestern parts of the United States. Look at the picture of the black widow, and tell how you can recognize this spider.

OBSERVE Find a garden spider, and put it in a jar which contains a small piece of moist cotton. Cover the jar with a piece of cheesecloth, held secure with a rubber band. Drop water on the cotton from time to time so that it does not dry out. If your spider spins a web, drop a small insect (grasshopper, moth, or fly) into the web, and watch the spider eat. The insect you drop into the web should be alive. Where does the spider's web come from? What is the purpose of the web? What does the spider do to make sure the insect will not escape? Does the spider eat the entire insect? What special structures enable the spider to suck the juices from its victim's body? ☐☐

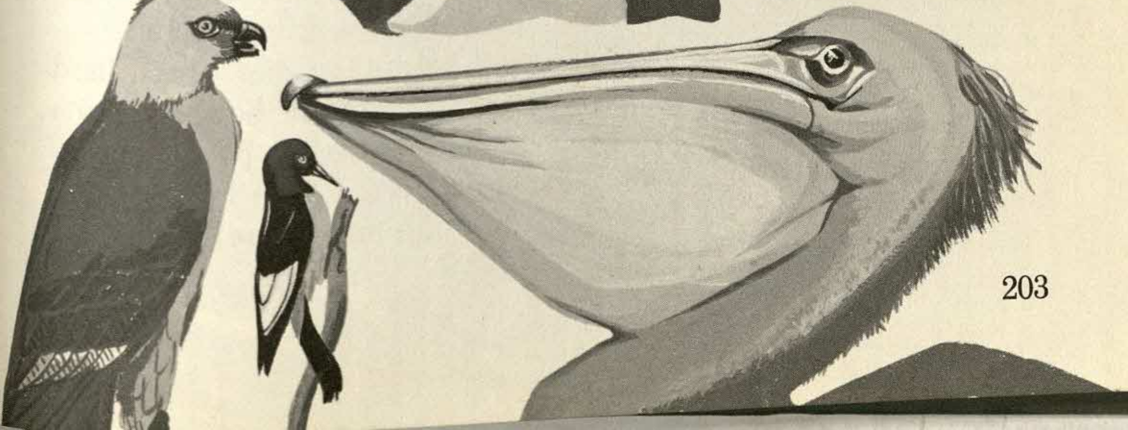
A mole lives underground and is nearly blind. How do you think the mole locates its food? This animal is especially shaped to get through the ground and to find its food as it goes. With its pointed nose, it plows through the earth. Front feet like shovels with long

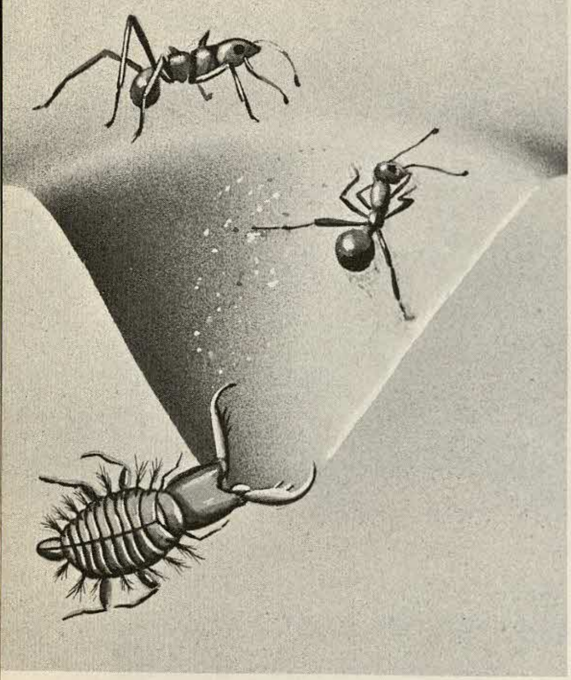


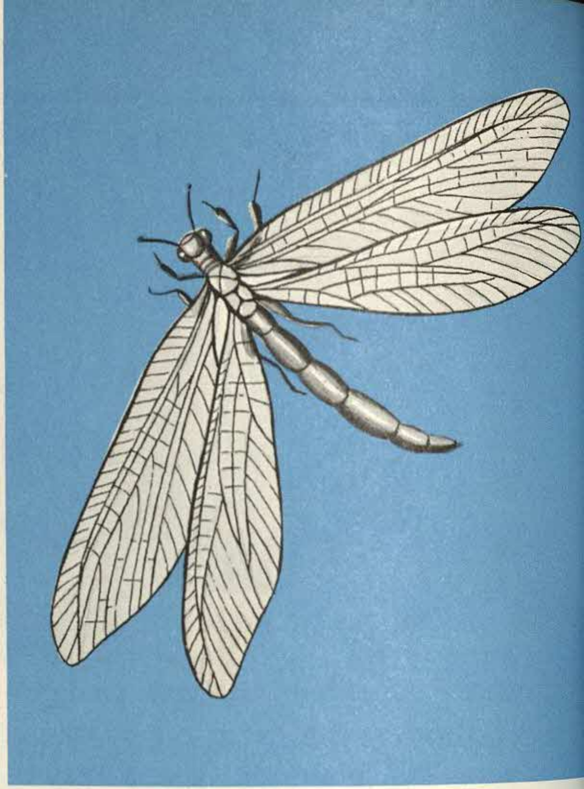
strong claws help the mole to dig and shovel the earth out of the way. The mole also has a very keen sense of smell and touch. Can you guess what foods the mole eats?

What does a bird's bill tell you about the bird's eating habits? The pelican's bill, which may be as long as 18 inches, has a pouch for scooping fish from the water. Find out how the bill of a finch, woodpecker, hawk, and duck help each bird to get food.

Some animals change their eating habits as they grow. Can you name some animals that eat different foods when they are adults than they ate when they were young? How do the eating habits of the adult dragonfly differ from those of the dragonfly nymph? The frog's eating habits from the tadpole's?







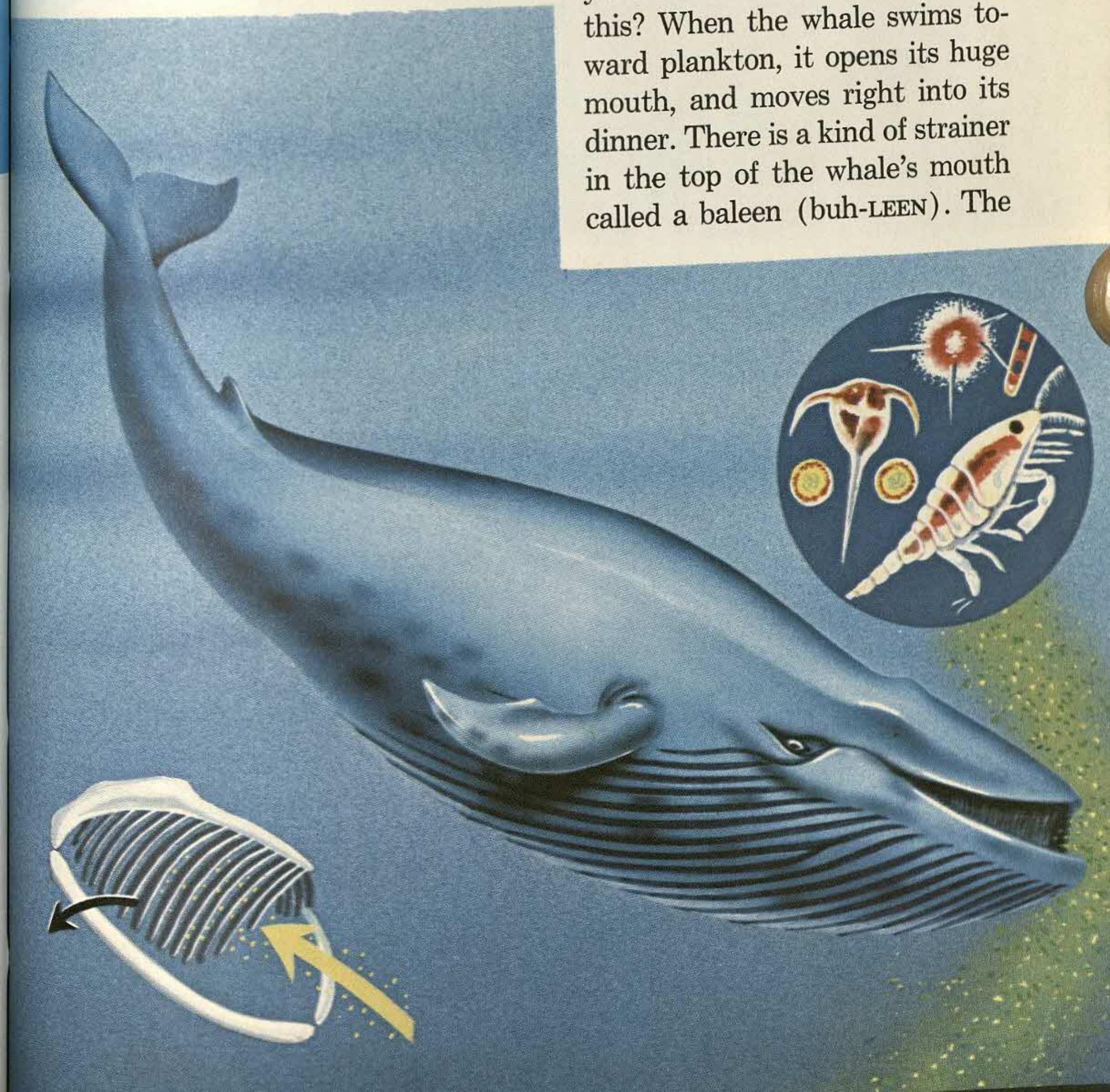
There is another insect, called an antlion, which looks much like the dragonfly and which develops from a most unusual little creature. The adult antlion is a lacy-looking insect with wings like those of the dragonfly. She takes no food at all. What kind of a digestive tract do you think she has? She lays her eggs in the sand. The eggs hatch into ferocious looking insects with powerful jaws. These furry creatures have short legs and a gray color which blends with the sand.

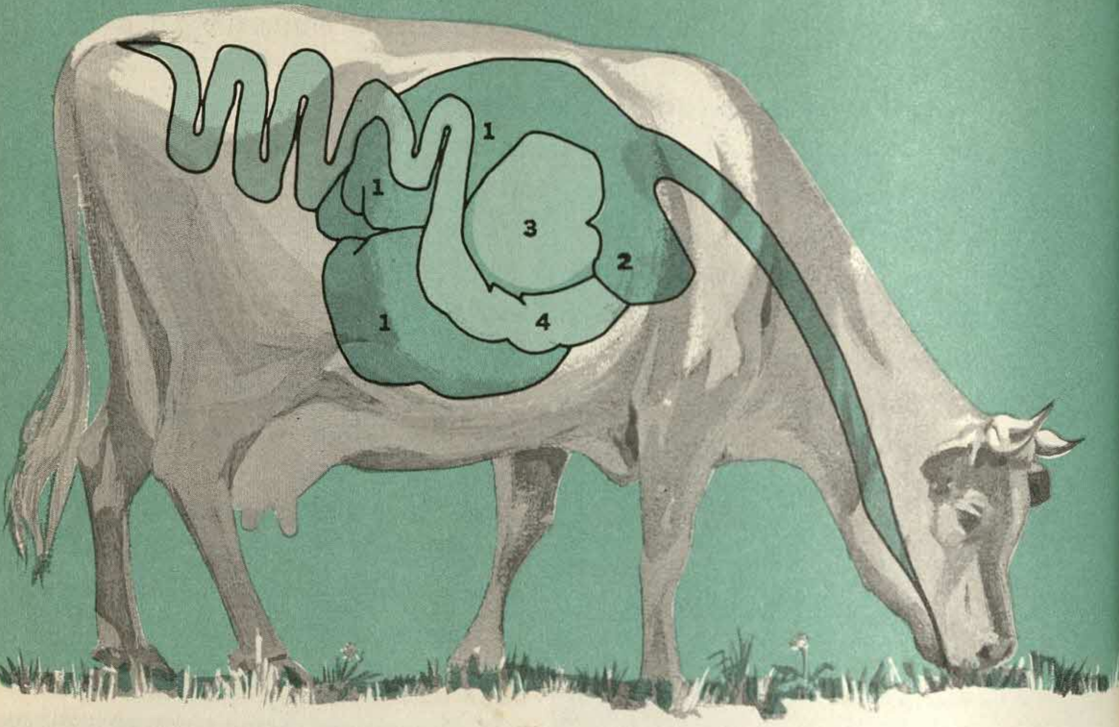
The young antlion walks backwards. Does this sound like a very good way to search for food? It may seem likely that the antlion, walking backwards, could easily become food for another animal. However, this little insect cleverly builds a trap by backing through the sand, and throwing out the sand with its head. The antlion buries itself at the base of the pit, and waits. A luckless ant loses its footing in the loose particles of sand, and slips into the pit. The more the ant struggles to free itself, the farther it slides down the pit, and finally slips into the jaws of the waiting antlion.

The antlion pierces the hard outer covering of the ant with its jaws, and injects a poison into it. This injected fluid kills and digests the ant before it is taken into the antlion's stomach. At last the antlion's dinner is ready. Eating the meal is a simple process; the captor sucks the digested ant into its own stomach. An antlion may have to wait a long time for an ant to come by, but it is not in a hurry. A year or two may pass before it completes its growth, because its food is difficult to get.

Why do large animals usually eat good-sized animals and plants? It takes a wild elephant about eighteen hours a day to gather enough grass to feed itself. What would happen to an elephant if it ate only mosquitoes?

Strange as it may seem, the largest of animals, the blue whale, feeds on the smallest sea animals and plants, called plankton. Do you know how the whale does this? When the whale swims toward plankton, it opens its huge mouth, and moves right into its dinner. There is a kind of strainer in the top of the whale's mouth called a baleen (buh-LEEN). The





baleen allows the water to pass out of the whale's mouth, but it catches the plankton inside for the whale to swallow. For the whale, this is a very satisfactory method of getting food. In fact, up to two tons of plankton have been found inside a whale's stomach. Why is it necessary for the whale to have such a big mouth?

You have read about some rather unusual animals and their ways of getting food. Observe some of the animals you see every day. What interesting eating habits do these animals have?

How Animals Digest Their Food

Have you ever watched a cow chewing as she rests in the shade of a tree? Did you ever wonder why the cow keeps on chewing so long? How does a cow digest grass?

The cow has front teeth called incisors (in-SAI-zuhrz), which are very much like scissors. Incisors cut the grass, which is then mixed with a great amount of saliva, and swallowed without being thoroughly chewed.

The cow has four sections, or chambers, in her stomach. The first chamber, the rumen (ROOmuhn), is much larger than the other three. Most of the food collects in the rumen after being swallowed. The food then passes into the second chamber, where it is softened by fluids and formed into soft masses called cuds.

While the cow is resting, she brings a cud back into her mouth, where her large, flat teeth grind up this food. The food is mixed with more saliva and swallowed a second time. It then passes through the second, third, and fourth chambers. In the fourth chamber, true digestion takes place. Food then passes into the intestine, where digestion is completed.

Cows do not eat meat. Their proteins come from bacteria that live in the rumen and are swallowed with undigested grass materials. The bacteria are then digested in the cow's intestine.

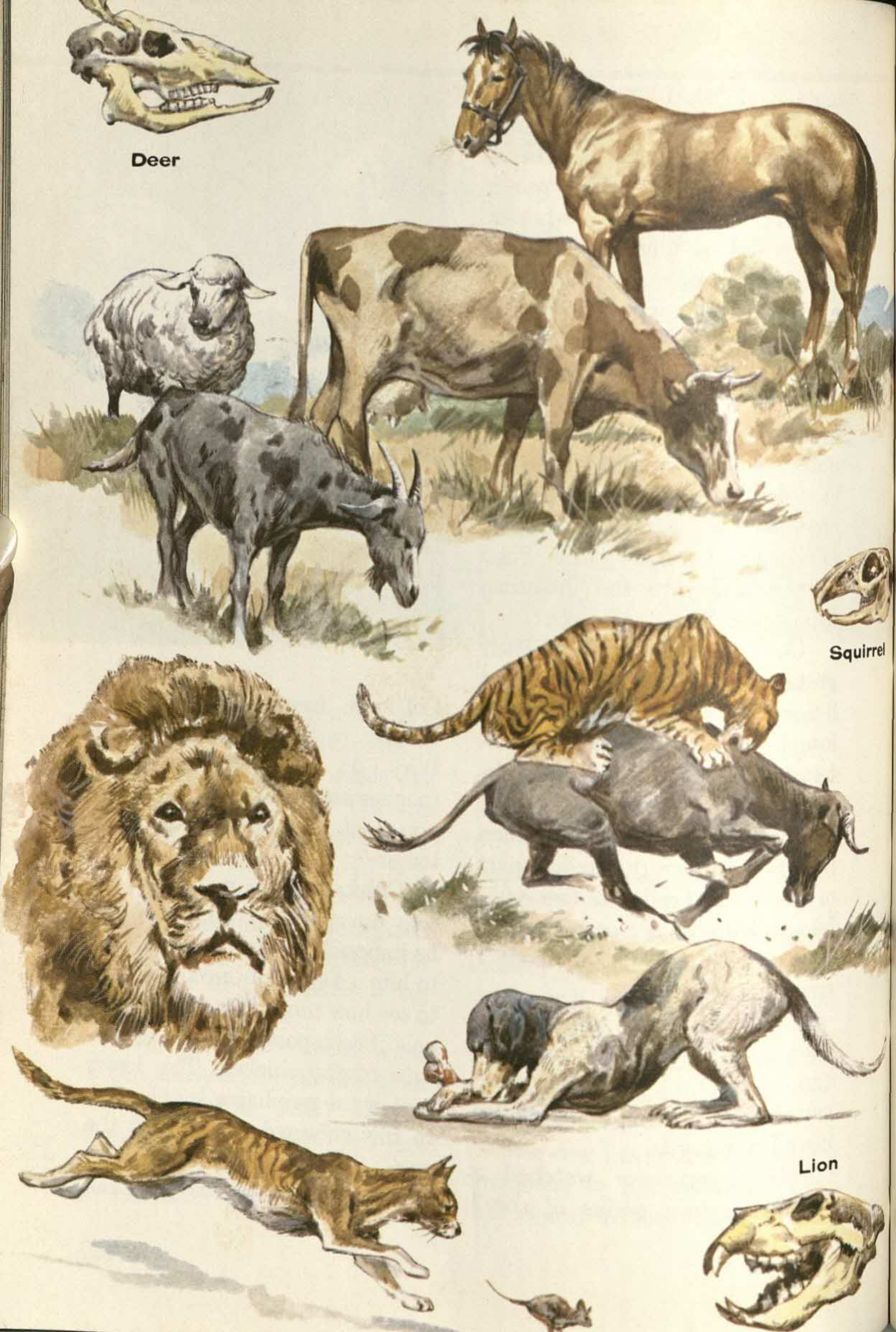
Bacteria in the cow's rumen help break down the stringy part of grass, called cellulose (SEL-yuh-lohs). Cellulose is a carbohydrate and supplies one of the foods a cow needs.

Cows and other animals that chew a cud are called ruminants (ROO-mih-n'nts). Giraffes, deer, camels, sheep, goats, and antelope are all ruminants.

Have you ever watched a chicken eating grains of corn?

Chickens have small, pointed tongues with a hard covering. Why do you suppose their tongues are hard? How fast could you pick up corn with your tongue?

Chickens have no teeth, yet they can eat hard corn that would be impossible for us to chew. Try to bite a kernel of uncooked corn to see how tough it is. Whole kernels of corn pass down the esophagus of the chicken. The lower part of the esophagus is enlarged. In this enlarged part, called the crop, corn is stored. Little by little, the corn passes into the


Deer
Squirrel
Lion

Tapeworm from a rabbit.

stomach. Part of the stomach is made up of a muscular gizzard. The gizzard is made of thick muscles. If you could see a chicken gizzard before it is cleaned out, you would see gravel in it.

The next time your mother prepares chicken for dinner, ask her to let you see the gizzard. Have you ever seen a chicken pecking at small stones? Why do we put bird gravel in bird cages? Did you know that in the gizzard this gravel takes the place of teeth for the bird? What happens to the tough corn in the chicken's gizzard? Do we need stones in our digestive tract?

Some animals, such as the adult antlion, have no digestive tracts at all. These animals either live a very short time (the May fly lives only one day), or get their food already digested.

Animals which have no digestive tract, and live in the intestinal tract or some other part of another animal or plant are called parasites (PAIR-uh-sytes). Tapeworms live in the digestive tract of another animal; they live off food the other animal has already digested.

Grazing animals, such as cows, horses, sheep, and goats, are plant-eating animals, or herbivores (HER - buh - vorz). Lions, tigers, dogs, and cats are meat-eating animals, or carnivores (CAR-nuh-vorz). Which is usually easier to chew, meat or vegetables? Look at the pictures of a squirrel's teeth, a lion's teeth, and a deer's teeth. Which animal do you think is a carnivore?

An animal that eats both plants and animals is an omnivore (AHM-nuh-vor). In which group does man belong? Is a bear an omnivore? What other omnivores can you name?

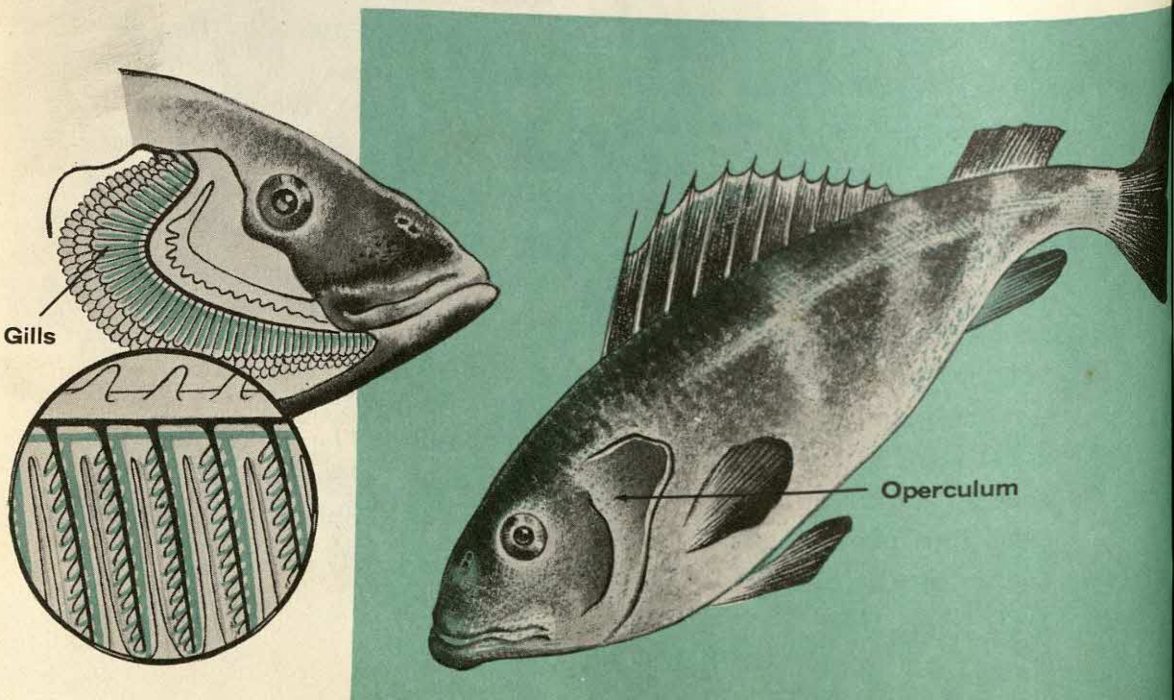
Animals Get Oxygen

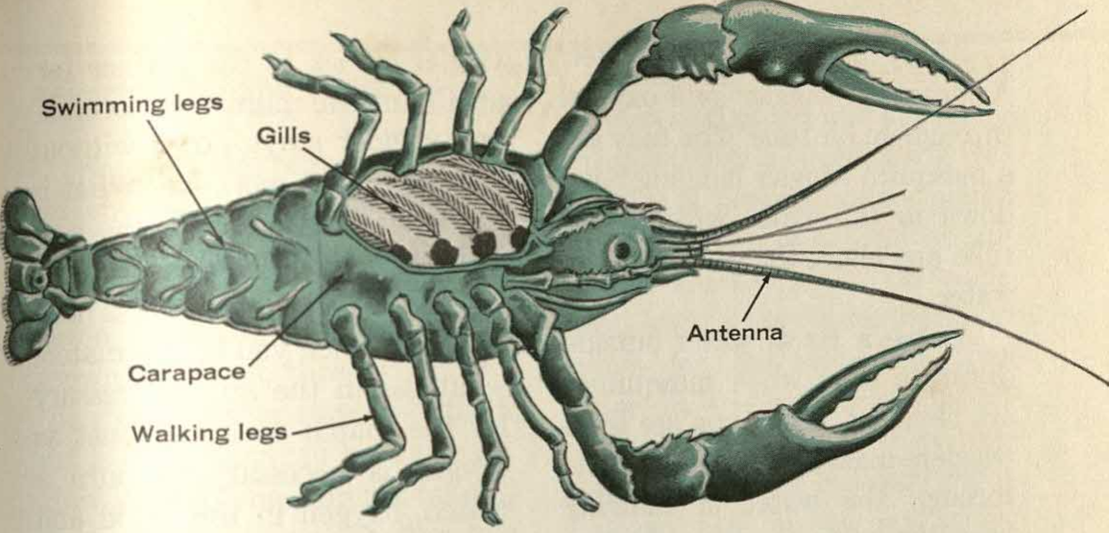
Animals have another need that is as great as their need for food. All animals must get air. Even fish need a gas from the air.

OBSERVE Place a fish in water that has been preheated and then cooled in a covered jar. Observe what happens. Return the fish to the regular aquarium immediately so that it does not die. ☐☐

What is the gas in the air that you need in order to stay alive? Do other animals need the same gas? Animals have many ways of getting oxygen. Remember the five groups of vertebrates—the fishes, reptiles, amphibians, birds, and mammals. Which of these animals have lungs for breathing? Watch a fish in the aquarium. Why does it open and close its mouth? Do you notice a movement of the covering on the fish's side? This cover is an operculum (oh-PUR-kyu-lum). The operculum covers breathing organs called gills. Gills serve the same purpose for the fish that lungs serve for you and for many other animals. The gills of fish are thin and ribbonlike. Fish use gills to take oxygen from the water.

How long can you swim underwater? Fish can get oxygen from water, but mammals and other air-breathing animals cannot. Both lungs and gills are supplied with large numbers of blood vessels. Why does blood come into the gills and lungs? How is the oxygen that comes into the lungs and gills carried to all parts of the



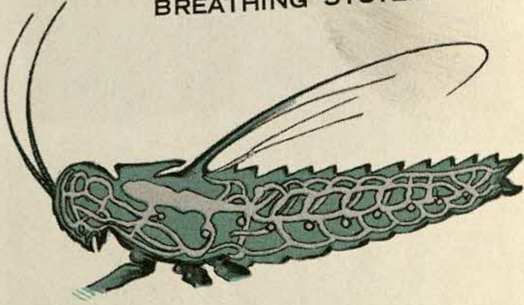


body? Porpoises and whales are mammals. Why do they have to come to the surface of the water to get air?

In our bodies, the diaphragm contracts and relaxes, and forces air into and out of the lungs. The frog has no diaphragm. Watch a live frog or toad. How does it force the air into its lungs? What part of the frog moves regularly? Count the number of times per minute that a frog breathes. Do you breathe as fast as the frog?

Some invertebrates, such as clams and crayfish, also have gills. The crayfish has gill chambers under its hard outer shell, which is called a carapace (KAIR-uh-pase). Delicate, plume-like gills take the oxygen out of the water. As the crayfish moves its legs, water is constantly kept circulating over the gills.

Grasshoppers and other insects do not have lungs or gills. Have you noticed the little openings in a grasshopper's side? These openings lead to tubes inside the grasshopper's body. Oxygen moves through these tubes very slowly. The grasshopper has no pumping organ. Would this breathing system provide enough oxygen for a large animal? Could this be one reason why insects are so small?



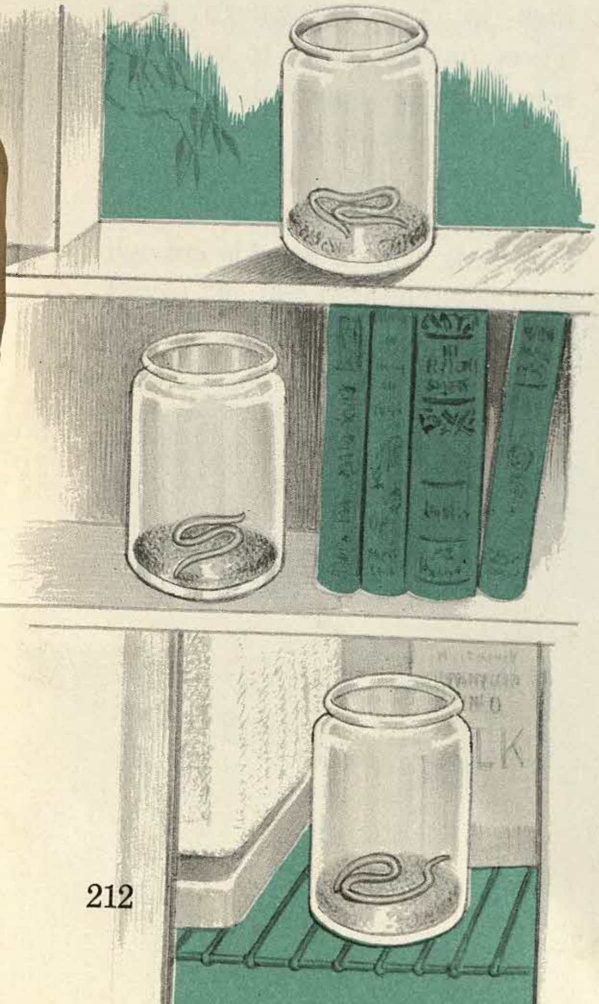
Many insects live in the water. A mosquito wiggler gets oxygen through an air tube. You may see a mosquito wiggler hanging head down in the water with its air tube just above the surface of the water.

Leave a jar of water outside during a time when mosquitoes are plentiful. When you see little wigglers making lunging motions through the water or hanging from the surface, put a piece of screen across the top of your jar.

Watch one wiggler. Count the number of times per minute the wiggler comes to the surface for air. Count the number of seconds one wiggler stays down without coming up for more air. What is the longest time any of the wigglers stay under water?

Why do all these animals need oxygen? When you light a match, what gas in the air is necessary for the match to burn? Just as oxygen is necessary to burn a match, oxygen in the blood and tissues is necessary for "burning" food. This "burning" releases energy for movement. The body needs less oxygen when movement is slower.

DESCRIBE Put three earthworms in three separate jars that contain moist soil. Put one jar in the direct sunlight, one in the classroom out of the direct sunlight, and one in the refrigerator. After several hours, take all the earthworms out and shake off the dirt. Place them on wax paper or newspaper. Watch for the pulses of blood moving toward the head. In which earthworm is the pulse beating faster—the one kept in the warmer place or the one in the cooler place? Which worm is getting oxygen faster to all the parts of its body? Every part of the body needs oxygen. Does an animal get more oxygen when it is active or when it is inactive?

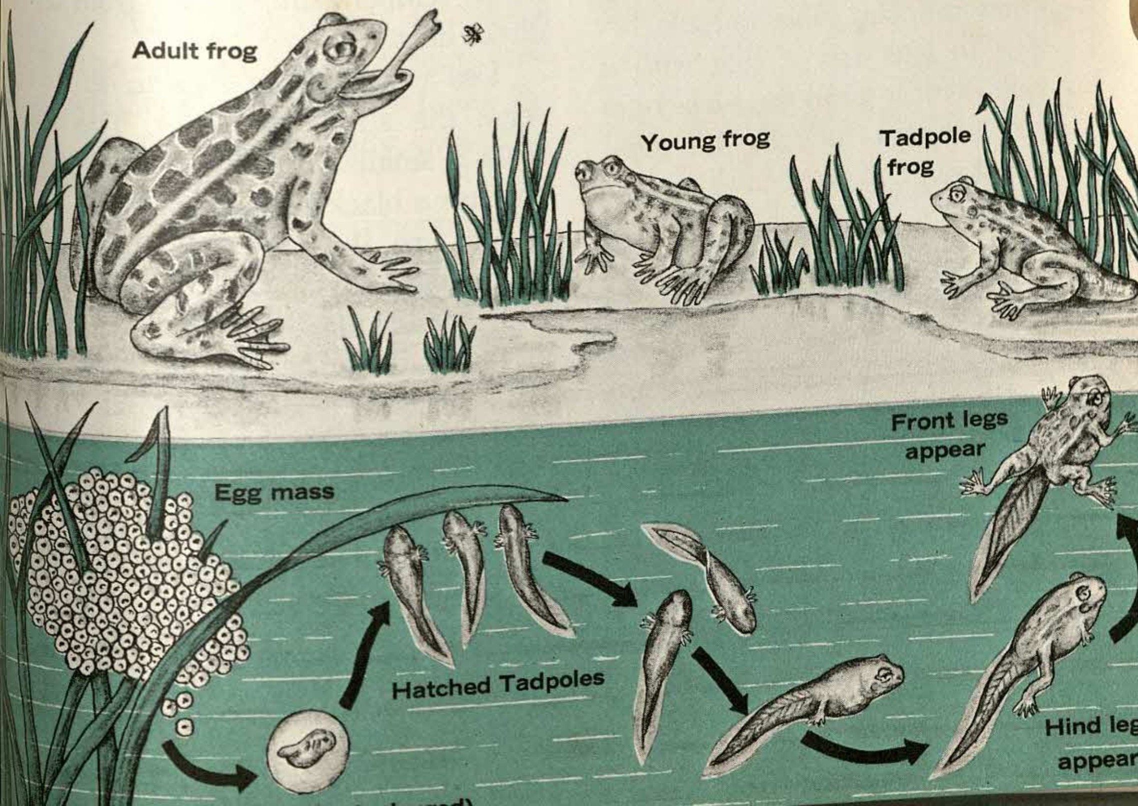


Animals Grow and Change

Some little puppies become grown dogs in less than a year. A baby elephant weighs more than 200 pounds when only six or seven weeks old. A tiger is full grown in about three years. At the age of two or three months a rat is old enough to be a parent. How long do you think it takes a butterfly to mature? Within two weeks a house fly is grown. Within three more weeks it can be a grandmother.

Do you have a young pet? If so, keep a record of its size and other changes you can see.

DISCOVER You can watch a tadpole as it grows and gradually changes into a frog. Look for frogs' eggs floating among plants along the edge of a pond in late spring. Gently scoop up some eggs, and bring them back to school for the aquarium. The water in the aquarium should come from the pond where you gathered the eggs. Put only about a dozen eggs in one aquarium. Put some green plants in the aquarium to provide sufficient oxygen for the tadpoles when they hatch. Also put in a large stone that juts out of the water. Cover the aquarium with a screen.



A tadpole has a little beak-like mouth, and eats green scum and algae. In warm weather the tadpoles of the leopard frog begin to change into frogs within a few weeks.

Watch your tadpoles change into frogs. On either side of the tail, hind legs begin to appear. As the legs grow longer the tail begins to get shorter. On a certain day each week observe the legs and tail of the tadpoles. Keep a record of your observations.

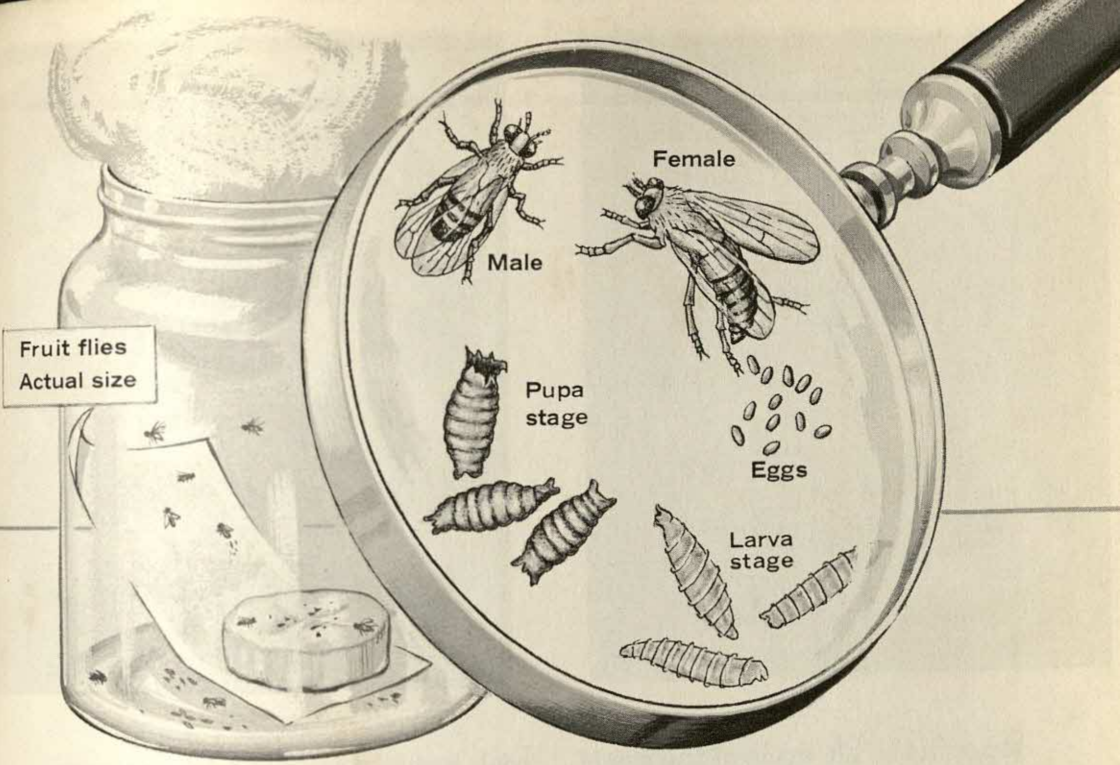
When do you first notice the front legs? What happens to the gills? Little teeth begin to appear inside the upper jaw. The little beak-like mouth disappears. A long tongue develops so that the tadpole can eat insects, and even other tadpoles. The tadpole begins to look like a frog with a tail. It must go to the surface for air, for now its gills are gone. What does the frog have instead of gills?

If you plan to keep the tiny frogs, you will have to provide a new home for them. Place a shallow dish or pie plate in an empty terrarium. Pack soil around the dish to form a hill sloping away from the dish. Add a few stones, twigs, and moss. Fill the dish with water. Put the frogs in the terrarium, and cover it with a screen to prevent them from escaping. Your frogs will eat live insects (ants, June bugs, small flies) and small worms.

The change which a tadpole goes through as it turns into a frog is called metamorphosis (*met*-uh-MOR-fuh-sis). Metamorphosis means change of form. Do you know other animals that change in form while they grow?

EXPLORE Put a piece of ripe banana and a strip of paper in a jar. Stand the jar outside for 24 hours. If you are successful in attracting fruit flies to the banana, cover the jar with a piece of cloth held secure by a rubber band (or plug the top of the jar with cotton). Keep the jar at room temperature, away from direct heat.

Use a magnifying glass to observe the adult fruit flies. The male is smaller than the female, and has a black-tipped abdomen. Where are the eggs deposited? What color and size are the eggs? The second stage in the life cycle of the fruit fly, called the larva stage, occurs a few days after the eggs appear. The third stage is called the pupa stage. About 10 days after the egg is laid, the adult fruit fly emerges from the pupa. Because there are four stages in the life cycle of the fruit

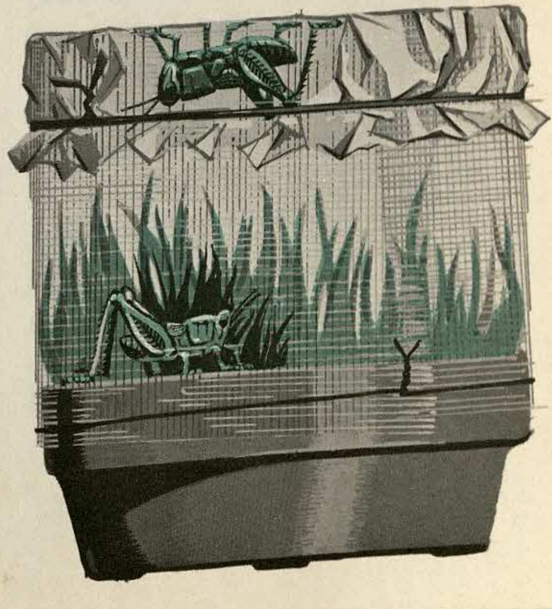


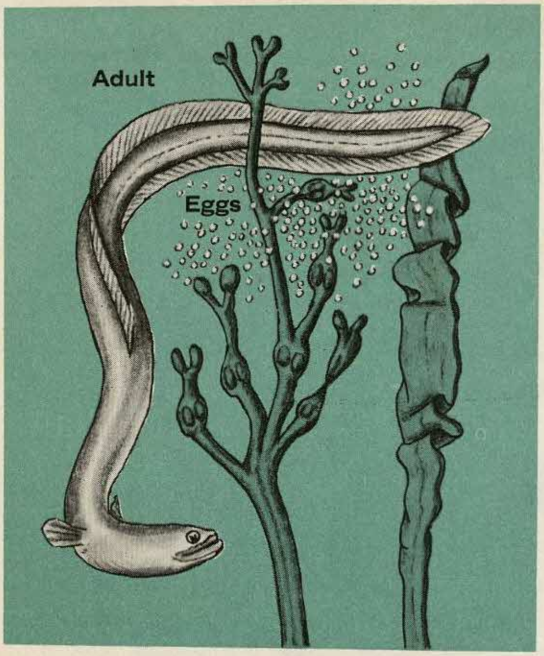
fly—egg, larva, pupa, and adult—we say that the fruit fly undergoes complete metamorphosis.

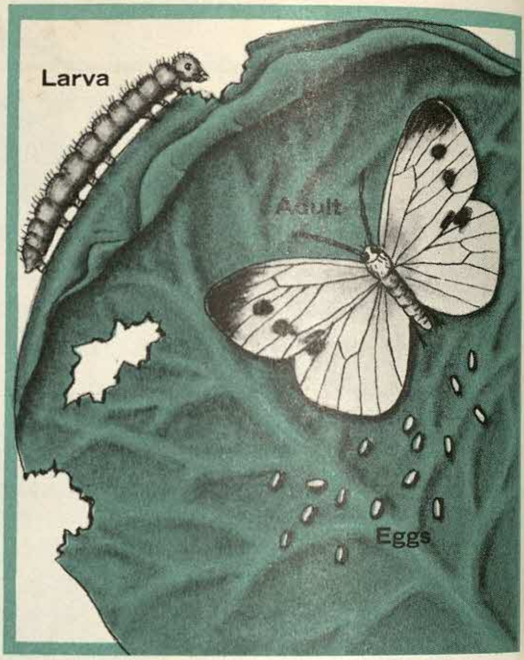
You may want to watch the growth, development, and changes in the life of a house fly, grasshopper, butterfly, mosquito, or beetle.

The female grasshopper lays her eggs in a hole in the ground during the autumn. This hole is about an inch deep, and is in a grassy place. In the spring, young nymphs hatch and start searching for food. Look for such a grasshopper nest. Dig up the eggs with the soil and grass, and put them in a low flowerpot which has gravel in the bottom.

Keep the grass watered so there will be food for the young nymphs when they hatch. Screen the flowerpot with wire as shown in the picture. Cover the top of the wire with cloth or plastic. You will observe that there is no pupa







stage in the life cycle of the grasshopper. We call this kind of life cycle incomplete metamorphosis.

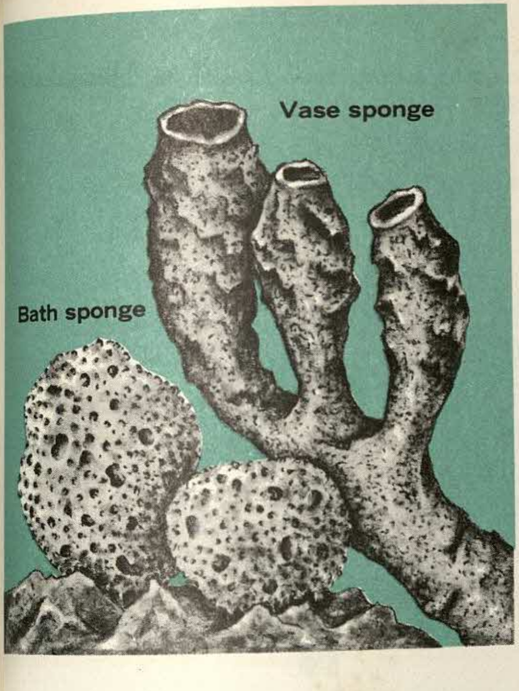
Animals Reproduce

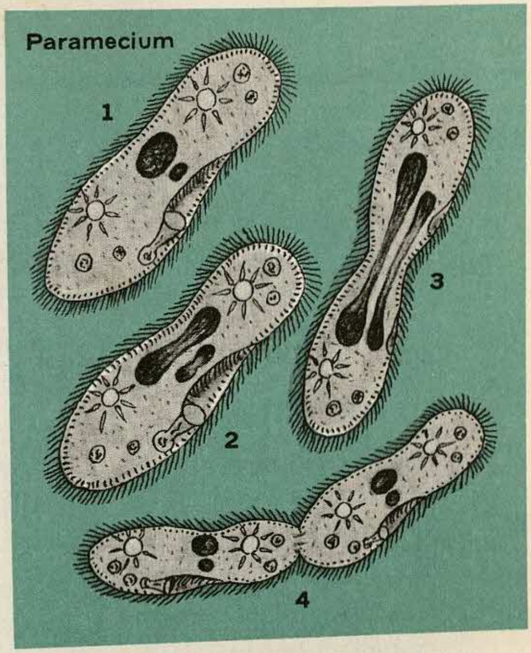
You already know that chickens are hatched from eggs which the hen lays. All other birds and some snakes also lay eggs. The eggs are formed inside the body of the mother animal. Before such eggs are laid, they are covered with a strong protective shell. Why do eggs of birds and snakes need this shell?

Some animals lay eggs that are not protected by shells. Their eggs must be laid in water or in moist places. Do you recall some of the animals whose eggs are laid in water? The toad is a land animal, but it, too, must lay its eggs in water because they would dry out on land. Where does the house fly lay its eggs? Where does the snail lay its eggs?

The instinct to provide for the young is one of the best known characteristics of the animals you are familiar with. Animals that care for their offspring after birth usually have few offspring. How many little birds do you usually see in one nest? How many puppies are usually born in the same litter? Do birds and dogs take care of their young? What other animals care for their young?

Some animals take little or no care of their young. These animals usually produce many offspring. The female eel, for example, lays





enormous numbers of eggs, and exercises great care in selecting the right place for her eggs. The female eel has been known to migrate thousands of mile to get to the Sargasso Sea. There she spawns. She lays millions of eggs, and then she dies. Locate the Sargasso Sea on a map.

The cabbage butterfly deposits her eggs on cabbage leaves. When the larvae hatch, they can munch on the leaves. Of the three or four million eggs a codfish lays, only a few become adult codfish. What happens to the others? Do you think a fly lays many eggs? How could you find out?

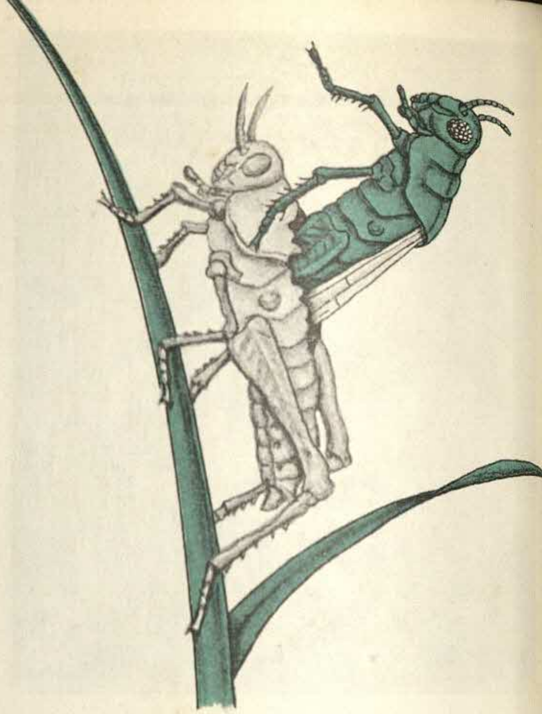
Sponges can reproduce by a method called "budding." Groups of cells enlarge on the parent sponge, forming a "bud." This bud breaks off and a new sponge is made.

Some animals reproduce very simply. The one-celled animal called a paramecium (*pair*-uh-MEE-shee-um) "pinches" in two, forming two "daughter cells" which are just like the parent paramecium. If you look through a microscope and if you are patient enough, you may be able to see a paramecium divide in two. Each paramecium has a mouth, little food storage places, a pump for getting rid of waste, and hair-like projections called cilia (SIL-i-uh) for moving. If you look at pond water through a microscope, you may be able to see other one-celled animals reproduce.

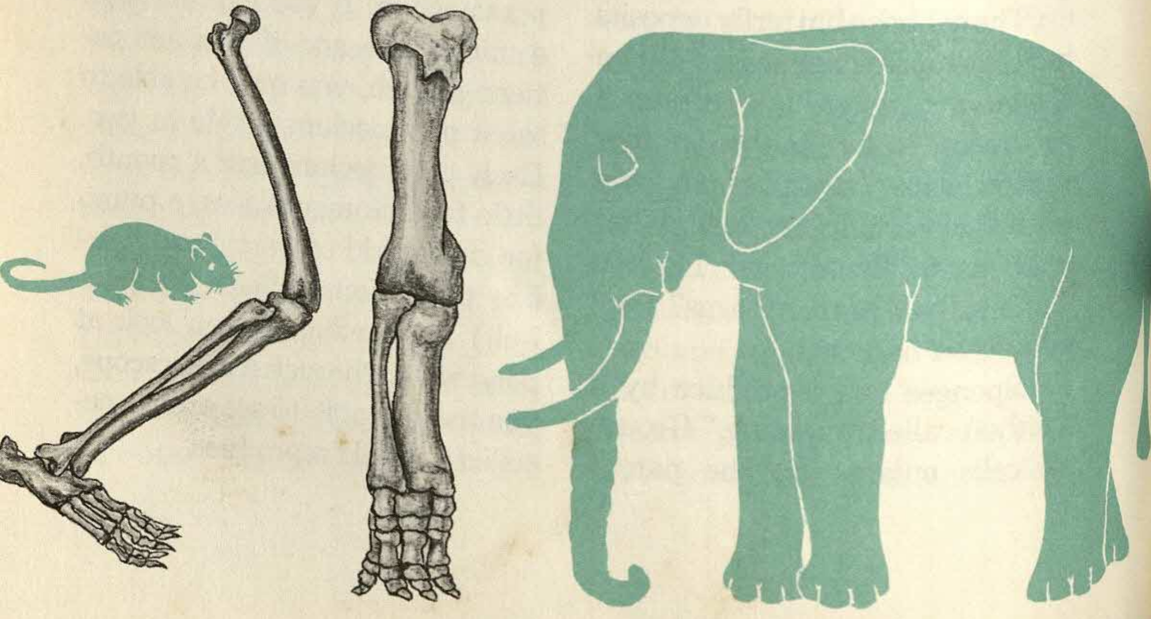
Animals Are Different Sizes

What is the largest animal you have ever seen? Would this animal fit in your classroom? The blue whale may be more than 100 feet long. How many walls would you have to remove in your school if you wanted to provide room for a blue whale?

Why does the whale grow so large, while the ant stays so small? Even if the whale had legs, it could not live on land. Its bones would not be big enough or heavy enough to hold up its huge body. Its bones would break and crumble. What holds the whale up in water? Do you feel lighter when you float in water than you do when you are on land? In the picture you see the leg of a mouse and the leg of an elephant drawn to the same size. Which one has a heavier bone for its size?



Insects have exoskeletons that do not permit them to grow very large. Have you ever seen a grasshopper break through its old exoskeleton in order to grow larger? This shedding of the exoskeleton is called molting. Grasshoppers molt about five times during their

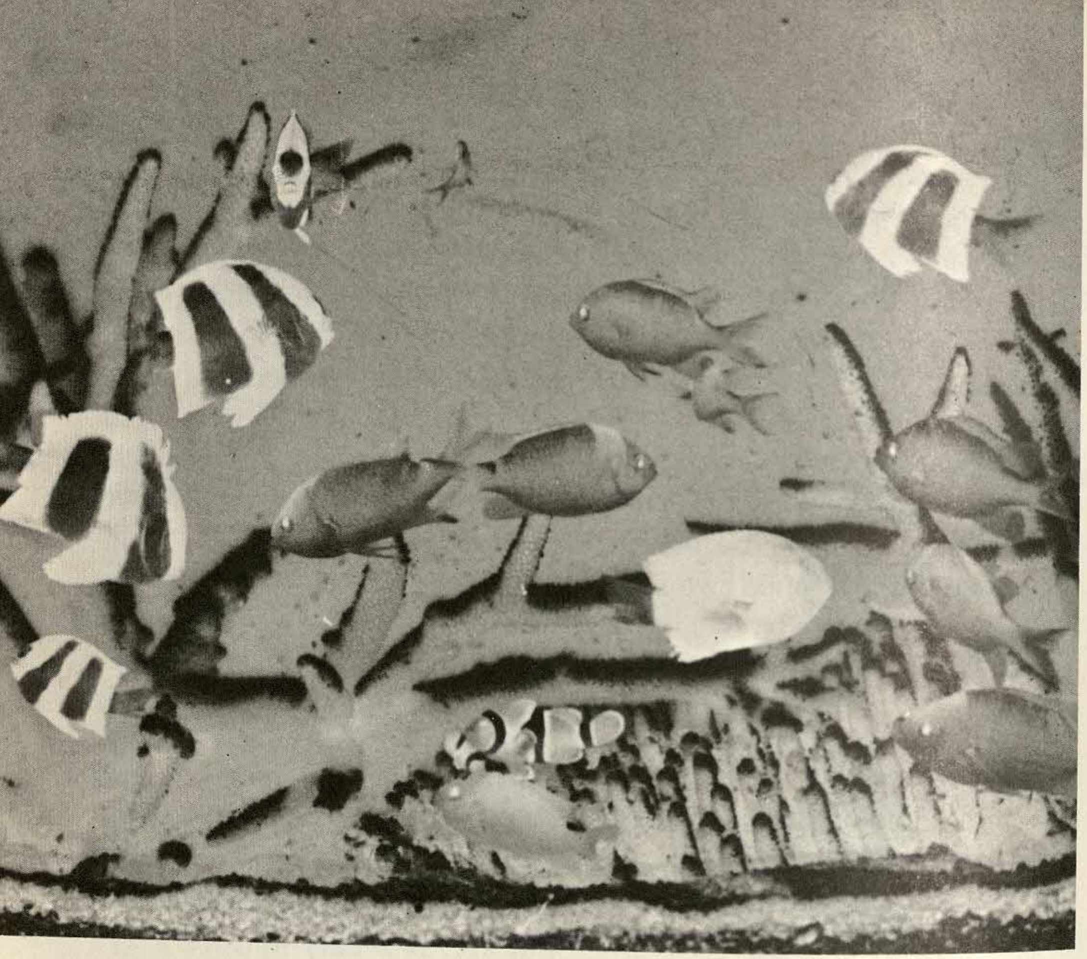


lifetime. As an insect gets larger, it needs a heavier skeleton. If the grasshopper grew much larger, it would be too heavy to jump very high.

MEASURE Catch a grasshopper and hold it in your hand. Then let it jump. Mark the place where you stood and the place where the grasshopper landed. Measure this distance with your ruler. If the grasshopper jumped two feet, it jumped a distance twelve times as long as itself. If you could jump a distance twelve times as long as your height, how far could you jump? Measure off this distance. See if you can jump that far. If your bones were lighter and your muscles were stronger, you could jump farther. If you were built this way, however, what would happen to your bones when you jumped? □□

Many insects have remarkable strength. An ant can carry another insect four times heavier than itself. The leaf-cutter can carry a leaf five times its own weight. If you had this much strength, you could carry your father on your back.

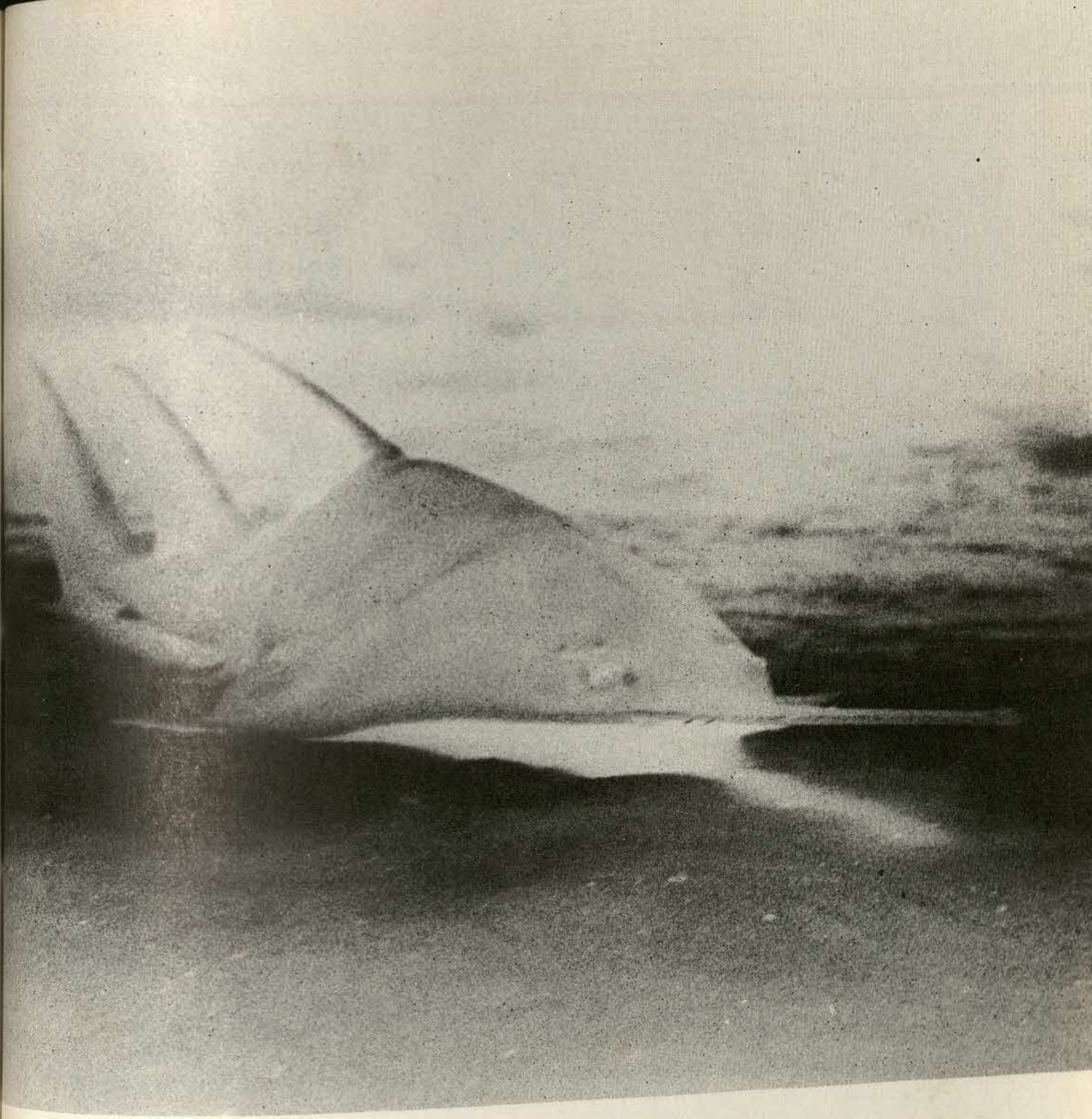
Insects can also move very quickly. Is it easy to catch a fly? Can you think of any other advantages of being small like a fly? What are the advantages of being large like a whale?



Animals Have Different Shapes

What parts of an airplane do you think of as you watch a bird in flight? Birds, like airplanes, have streamlined shapes that help them fly easily. Large feathers in a bird's tail act as a steering device. In what position are the feet of a bird in flight? As a bird glides toward the earth, it lowers its feet as a plane lowers its landing gear. What are some similarities between a bird's wing and an airplane wing? Between a bird's head and the nose of a plane?

Why do you think animals have different shapes? Why are there rounded fish, flat fish, short fish, and long fish? Some fish, like angel fish, are practically flat. They are beautiful and very well suited to life in an aquarium or other quiet waters. They slowly move among the plants in the aquarium. Such fish *cannot* swim fast. Watch one to see how long it takes to get from one end of the aquarium to the other. Which moves faster, the angel fish or the guppy? Why?



Fish that must make their way upstream in swift waters have streamlined bodies. Swordfish are built like rockets and can swim faster than horses can run. Swordfish zoom through the water the way a rocket goes through the air. Which came first, the fish or the rocket?

Snakes have long, slender bodies. How do snakes move? Would snakes move as well if they were short and fat? Turtles are round and heavy. How do turtles move? Is it necessary for turtles to move quickly? Explain your answer.

Jelly fish are nicely rounded animals that float through the

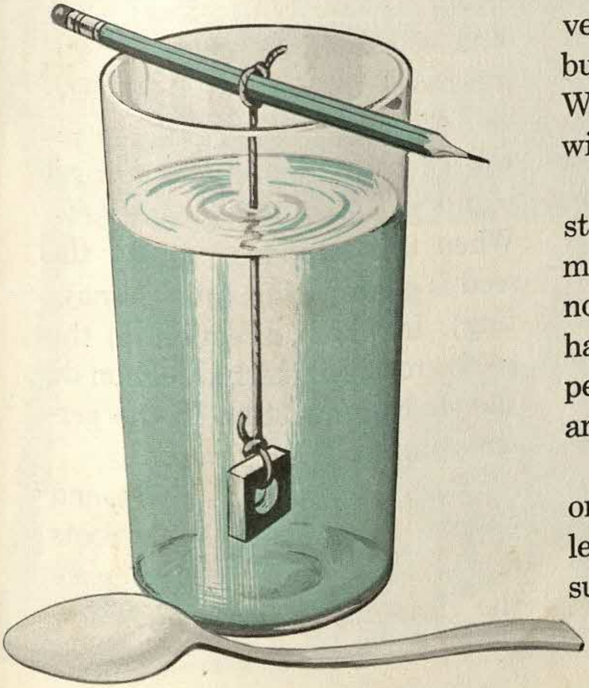
water. Would a jelly fish be able to move faster if it had a different shape? Does a jelly fish need to move fast?

Each of these animals seems to be adapted for life in a particular place. Each has the shape necessary for either swift or slow movement, and for travel in water, in the air, or on land. All animals have parts which help them get the food they need. Scientists wonder if the animals developed first and then found the right place to live, or if animals developed certain sizes and shapes to fit the places in which they lived. This question is still a great puzzle to scientists. What do you think?

Plants Are Alive

What are the signs of life in plants? How do plants grow? Do nonliving things grow?

COMPARE Dissolve twelve spoonfuls of sugar in a glass of hot water. Be careful to pour the hot water into the glass very slowly, so that you will not break the glass. Tie a string to a pencil, and suspend the string in the water. After several days, what forms on the string? How does the size of the crystals change from day to day? Is the growth of the crystals the same kind of growth you see in plants? How are the two alike? How are they different?



Plants Are Built to Fit Their Needs

Seed Plants

As we study plants we will spend most of our time with the plants that are the most familiar —those that produce seeds. Seed plants are the highest form of plant life today. How do seed plants react to their surroundings, get food, grow, and reproduce?

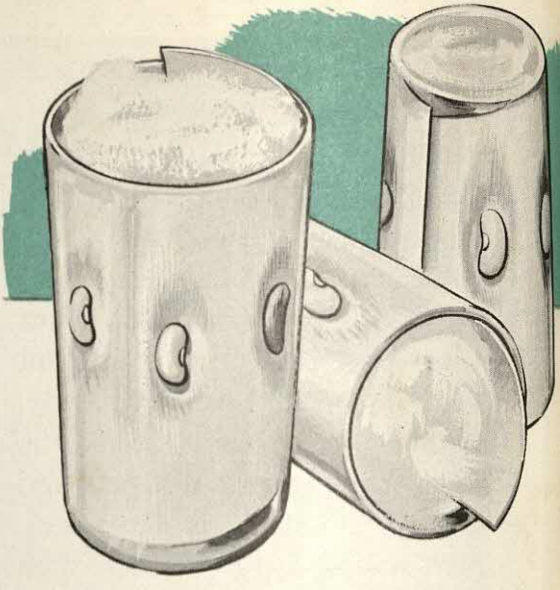
Plants React to Surroundings

Most plants are firmly fixed in the ground by a root system. Plants cannot move from place to place as animals can, so many people think that plants cannot move at all.

You have seen plants "move" on windy days. Unless the wind is very strong, plants do not break, but bend and sway with the wind. What structures enable plants to withstand the force of wind?

Many plants have flexible stems, which allow the plant to move. A heavy tree trunk does not usually move, but each leaf has a small flexible stem, called a petiole (PET-ee-ohl), which bends and allows the leaf to move.

OBSERVE Put a geranium or other house plant on a window ledge that receives a great deal of sunlight. After two days, observe



the position of the leaves. Turn the plant around, and two days later observe the position of the leaves again. □□

"Photo" means light. "Tropism" means a movement from within that is not the result of a wish or a desire. Why is the movement of plants toward light called phototropism (fo-TOT-ruh-piz'm)? The plant does not *think* that light would be good for it. A tropism is a natural movement that comes from within the plant. How are plant tropisms similar to animal instincts? How are they different? What makes *you* move into the shade on a hot day?

Scientists have an explanation for phototropism. They say there is a growth substance inside the plant. This substance is called an auxin (AWK-s'n). It is thought that the auxin, or growth substance, is affected by the light. Growth is more rapid on the side away from the light. Can you explain why this kind of growth would cause the plant to bend?

Some flowers respond to light. Can you name some flowers that open in the morning and close at night? Are there any flowers that open only at night?

DISCOVER Soak four bean seeds in water overnight. Get a drinking glass and a blotter. Roll the blotter into a cylinder, and release it inside the glass. The blotter should fit in the glass snugly. Put the seeds between the blotter and the glass, about half way between the bottom and the top of the glass. Stuff cotton into the glass. Water the cotton. You will have to keep the cotton moist throughout this activity. After a few days, the seeds will break open, and the small plants within will begin to grow. When this happens, we say the seed is germinating (JUR-mi-nay-ting). In which direction do the roots grow? In which direction do the stems grow? Sketch the germinating seeds each day.

Turn the glass on its side, and observe the growth of the roots and stems for a few days. Leave the glass upside down for a few days. In which direction do the roots grow? Do roots grow downward even when the seed is not in dirt? The response of roots to gravity is called geotropism (jee-OT-ruh-piz'm). Scientists think that auxins are also connected with this kind of plant movement.

ACTIVITY Construct a rectangular wooden frame with a screened bottom. Fill this box halfway with peat moss or excelsior, add some bean seeds, spaced evenly, and then cover the seeds with more peat moss or excelsior. Support the box between two tables so that you can see the screened bottom of the box. Keep the peat moss or excelsior damp. When the roots appear, observe the direction in which they grow. The response of roots to water is called hydrotropism (hy-DROT-ruh-piz'm). From your observations, which do you think is the stronger influence on plants — gravity or water? □□

One plant that will show you some very interesting responses is the mimosa plant, which you can grow from seed. What happens when you pinch one of the end leaves of the mimosa plant? Does a young leaf respond faster than an old leaf? Do you know any other plants that respond when touched?

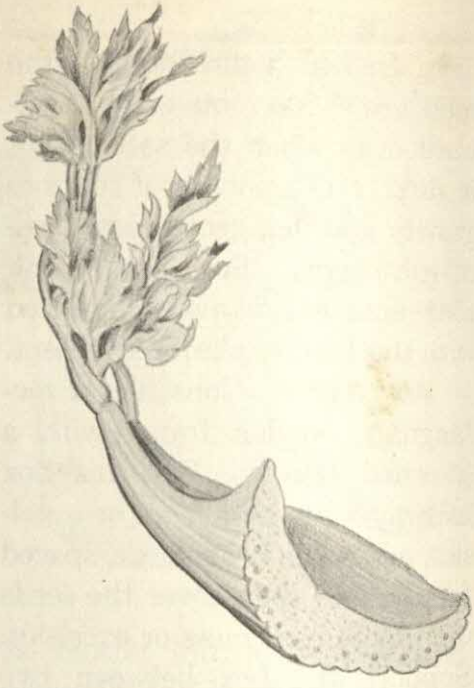
How Do Plants Grow?

You know that plants do not have mouths and digestive tracts, as animals do. How do plants nourish themselves? What special structures enable plants to get nourishment? What conditions are necessary for plant growth?

Plants Need Water

We take water through our mouths. What part of the plant absorbs water? What happens to plants that get no water? Examine the roots of your germinating beans with a magnifying glass. The tiny, delicate extensions growing from the outside layer of the root are called root hairs. How do you think root hairs help the plant?

EXPLAIN Taking one fresh stalk of celery, cut the bottom off the stalk, and put it into a glass which contains some colored water. Leave the celery in the colored water overnight. What change takes place in the appearance of the celery? What part of the leaves is colored first? Cut across the stalk in several places. How are the conducting tubes in the celery arranged? If the stem were round, how do you think the tubes would be arranged? After water enters a plant through the roots, how is it carried to other parts of the plant?



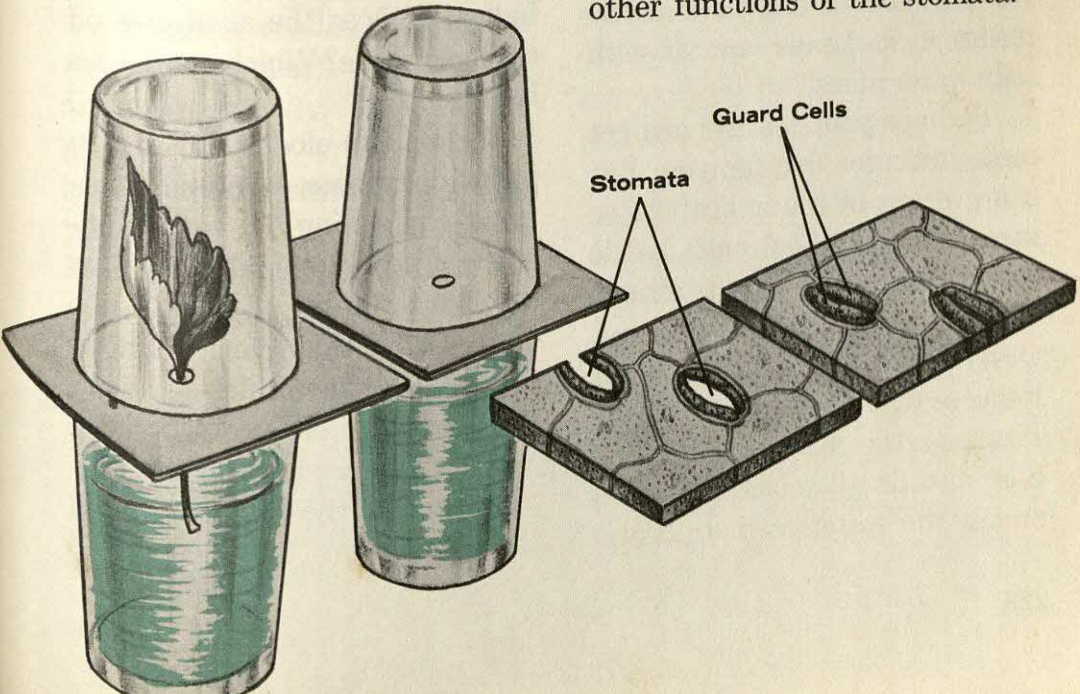
The following activity will show what happens to some of the water after it reaches the leaves.

ACTIVITY You will need four glasses and two pieces of cardboard. Make a hole in each piece of cardboard, as shown in the picture. Pour water into two of the glasses, and lay the cardboard over the glasses. Take a leaf from a geranium or coleus plant. Put the stem of the leaf through the hole in one of the pieces of cardboard. Be sure the stem reaches the water. Invert the other glasses over the pieces of cardboard.

The set of glasses with no plant is called a "control." Why do we use a control in performing a scientific activity? After several hours, observe both sets of glasses. What do you see inside the glass that contains the leaf? The loss of water vapor from plants is called transpiration (trans-puh-RAY-shun). Can you think of any purpose that might be served by water circulating through a plant? Do plants, like animals, have circulatory systems? ☐☐

If possible, get a prepared slide that shows the special structures through which water vapor escapes from the leaves of a plant. The small divisions in the plant that you can see with a microscope are called cells. The openings in the leaf through which water vapor escapes are called stomata (STOH-muh-tuh). A single opening is a stoma (STOH-muh). Stoma means little mouth. Each "little mouth" is formed by two special cells called guard cells. When the guard cells are filled with water, they become rounded and leave a small opening. When they contain little water, they come together, leaving no opening.

During a dry season, would you expect the stomata to be open or closed? In most plants, the stomata are found mainly on the lower side of the leaf. Can you think of any advantage to this location? Leaves that float in water have all of their stomata on the upper surface of the leaf. Why? You will later learn about other functions of the stomata.



Plants Need Carbon Dioxide

DISCOVER Get three empty jars with self-sealing tops. Put water in all three jars and a sprig of elodea, or other water plant, in two of the jars. Take a good-sized snail from the aquarium. Put the snail in one jar that has elodea in it. Leave one jar with only water in it.

Perhaps your teacher can get some indicator dye for you. Put a few drops of the indicator dye in each bottle. Seal each bottle tightly so that no outside air can enter and no inside air can escape. Observe for several days. What happens in each of the jars? Does the indicator change color? Carbon dioxide dissolved in water makes the water acid. Indicator dyes change color in the presence of acid; bromothymol blue turns green and methyl orange turns pink.

In which jar do you find change of color? What does this indicate? Does the snail give off carbon dioxide? Which plant looks healthier? □□

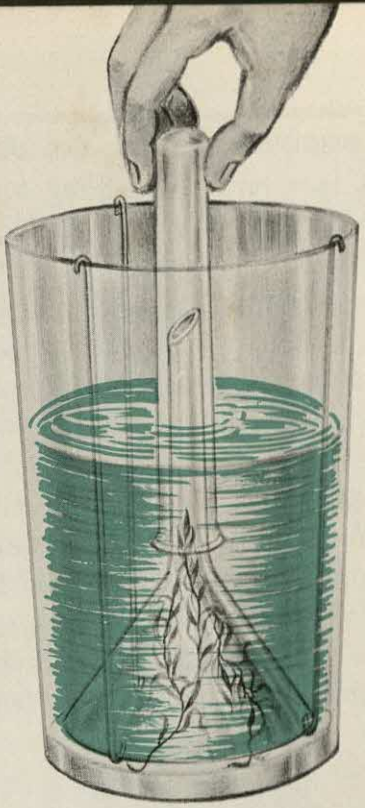
Plants like elodea that live in water do not need special structures for taking in carbon dioxide. Carbon dioxide can pass through the thin cell walls in the plant. Plants that live in air, however, usually have thick cell walls or some kind of outer covering. Why? In such plants, carbon dioxide enters the leaves through the stomata.

Plants Need Sunlight

Carbon dioxide and water are the raw materials for a wonderful process called photosynthesis (*fo*-to-SIN-thuh-sis). By this process green plants can make sugars and starches. How do plants get these raw materials? Do plants need anything for this process besides these raw materials of carbon dioxide and water?

OBSERVE Take two small green plants. Leave one in the sunlight, and cover the other with a large carton so no sunlight can enter. Water each plant the same amount. After a week compare the plants. What do you observe? Why?

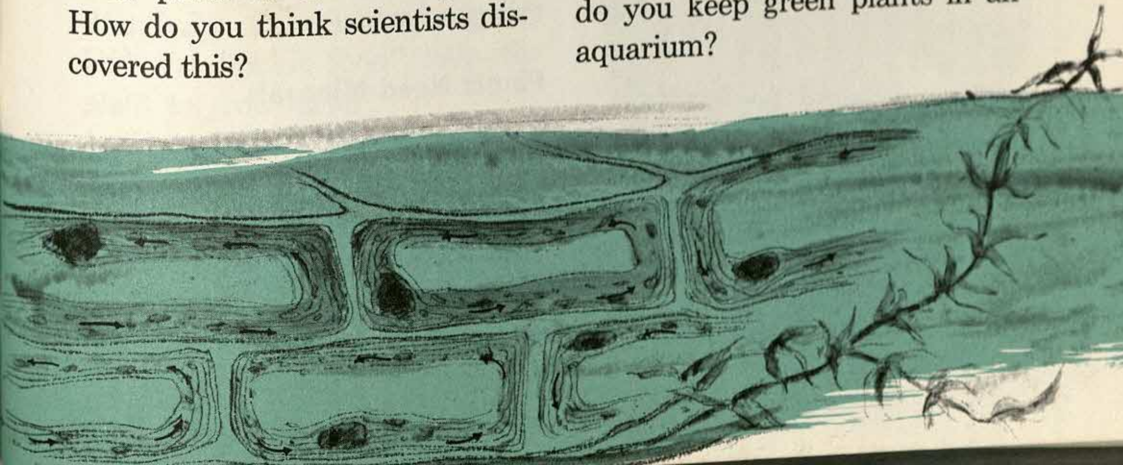
The green coloring matter of a plant is chlorophyll (KLAW-ruh-fil). Chlorophyll is contained in very tiny bodies in the cells. These tiny bodies are called chloroplasts (KLAW-ruh-plasts). Chloroplast means green body. These chloroplasts give the green color to leaves. Photosynthesis in plants takes place in the chloroplasts. How do you think scientists discovered this?



Plants Give Off Oxygen

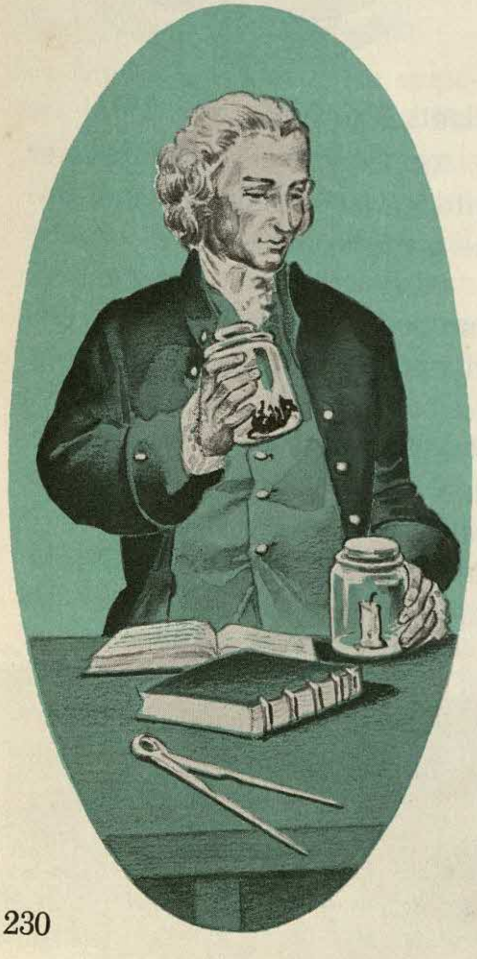
TEST Put elodea and water into a glass with an inverted funnel over the elodea.

Place a test tube over the small end of the funnel. Put the glass in a place where the sunlight will get to it during part of the day. Bubbles of gas should begin to go into the test tube. What is the gas? How could you test it? Why do you keep green plants in an aquarium?



DISCOVER Take two olive jars that have self-sealing tops. Put water in both jars. Put elodea or some other water plant from your aquarium in one of the jars. Put a snail in both jars. Observe for a week or two. What happens to the snail in the jar in which there is no water plant? What is the plant producing that the snail needs? The snail in the jar is also producing a gas that is good for the plant. What is it? □□

The fact that plants provide oxygen for animals has been known for almost 200 years. When Joseph Priestley put a mouse in a closed jar, the mouse soon died. Why? When he burned a candle in a closed jar, the candle soon went out. Why? Priestley concluded that the air in the jar had been "injured" by the candle and the mouse. He discovered that this "injured" air could be restored by a plant. When Priestley put a mouse in a closed jar containing a growing plant, the mouse did not die. He realized that plants give some kind of gas to the air which animals need. This gas was later called oxygen. Oxygen escapes through the stomata of a leaf during photosynthesis.

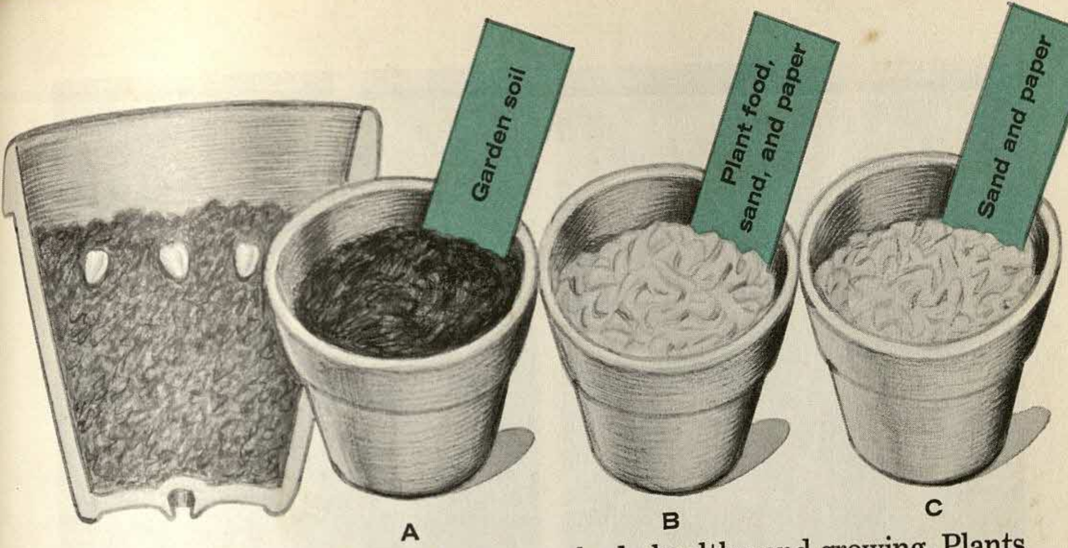


Photosynthesis is an amazing and very complicated process about which scientists still have much to learn. We do know that during photosynthesis two things occur. In the presence of chlorophyll and light, carbon dioxide and water combine to produce food for the plant. Then, oxygen is released as a waste product of this process.

Plants Need Minerals

You can show that a plant has needs other than carbon dioxide, water, and sunlight.

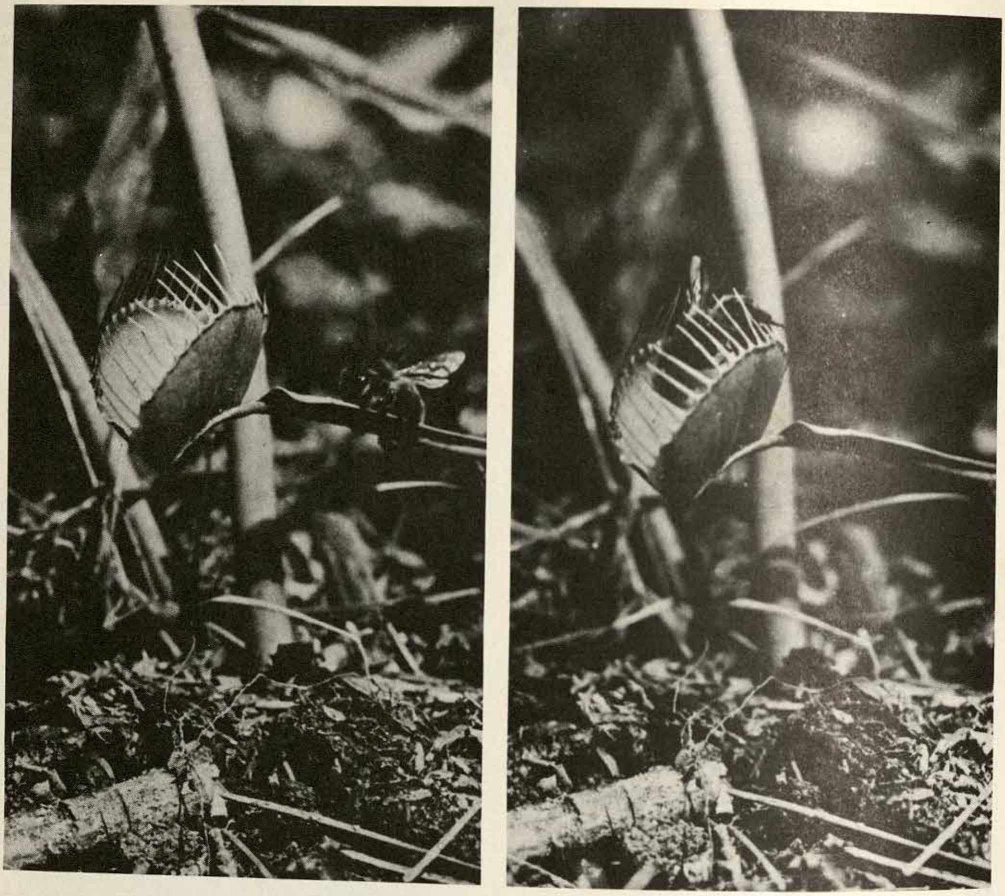
COMPARE You will need three flowerpots, a dozen corn



seeds or bean seeds, and some "plant food." You can buy "plant food" in variety stores. Soak the seeds overnight. Put rich garden soil in one pot, and sand in the other two. Put some paper in with the sand so that it will hold the water and "plant food." Add "plant food" to only one of the pots containing sand. Plant three or four corn seeds in each flowerpot about one-half inch below the surface. Mark the pots A, B, and C. List on each what you added. In which pot do the seeds germinate first? In which pot do the seedlings grow fastest? Does rich garden soil contain something that helps the plants to grow? Did the "plant food" help the plant to grow faster? □□

Have you ever stopped to think about what makes good soil? From your health studies, you know you should eat different kinds of food to keep your body healthy and growing. Plants also need a balanced diet. This diet is made up of certain minerals which are found in soil. Some of the most common of these minerals are sulfur, phosphorus, potassium, calcium, and iron. Compare this list of minerals with the list of ingredients on the "plant food" envelope. Sulfur and iron are needed for the production of chlorophyll in the plant.

Sometimes your body does not get everything it needs from the food you eat, so you have to vary your diet. Often the soil does not contain all the minerals needed by a certain kind of plant, so the farmer or gardener must use some kind of fertilizer on the soil. Fertilizers are most often needed to supply materials such as nitrogen, phosphorus, and potassium. Plants absorb these minerals, dissolved in water, through root hairs.



The Venus's fly trap.

Some Plants Eat Insects!

There are a few very strange plants which can capture and digest insects. If an insect steps into the open leaf of the Venus's-flytrap, the leaf snaps shut. The trapped insect is then digested by special fluids within the plant.

Plants Use Oxygen

Plants need oxygen for respiration and for burning up their foods, just as animals do.

ACTIVITY You will need two large jars. Fill one jar about half full of tap water. Heat some water for the other jar. The heating will remove air dissolved in the water, and therefore remove the oxygen. Then pour the heated water into the jar and add enough mineral oil to cover the top of the water. What is the purpose of the mineral oil? After the water has cooled, drop about five string bean seeds into each of the jars. Watch for the seeds to germinate. In which jar does germination take place? What gas do plants need in order to use stored food? □□

You have learned that during photosynthesis and transpiration, gases may enter and escape from the leaves of plants through openings called stomata. The stems of plants also have openings through which plants "breathe." These little openings are called lenticels (LENT-uh-selz).

You know that plants give off oxygen during photosynthesis. During respiration, plants take in oxygen.

Plants Can Store Food

Some of the food produced by plants is stored. In many plants, food is stored principally in the roots. What are some examples of such plants?

Some plants, such as celery and rhubarb, store food in their stems. A white potato is actually an enlarged part of an underground stem system called a rhizome (RHY-zohm). The potato itself is swollen with stored food.

We know that beets, carrots, radishes, and potatoes are good for *us*. Is this stored food of any use to the plant?

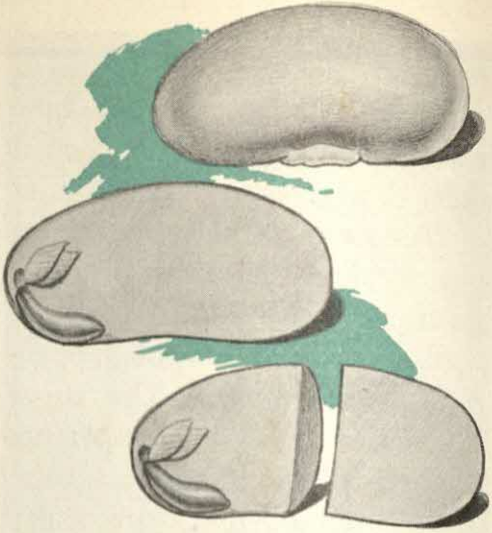
COMPARE Get a potato that has buds (sometimes called "eyes"). Cut out three chunks of potato with a bud in each one. Cut the first small, the second larger, and the third still larger.

Fill three small flowerpots with rich, moist dirt. Plant the three pieces of potato, one in each pot. They should be planted at the same depth, about one inch below the surface. Mark the pots which contain the smallest piece and the largest piece. Keep the dirt moist.

Check the flowerpots each day for the appearance of shoots. In which flowerpot does the new potato plant appear first? In which flowerpot is the new shoot the tallest? Do plants use the food they have stored? How do they use it?

DESCRIBE Soak three bean seeds overnight. Inside each seed is a tiny plant called an embryo (EM-bree-oh). Leave one seed whole. Split two of the seeds in half and discard the halves without the embryos. Keep the parts that contain the embryo. Cut one of these in half.

Plant the whole seed, the half seed, and the "one-fourth" seed in three separate jar lids filled with moist cotton. Label the jar lids. Keep the cotton moist throughout the activity. Which seed produces the biggest plant?

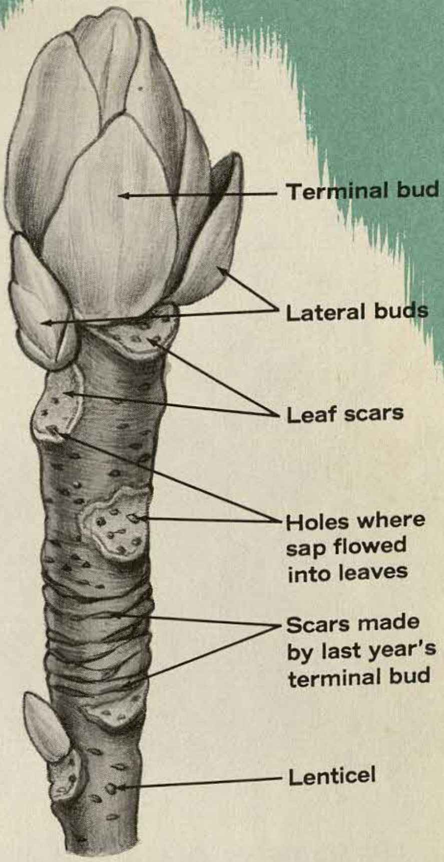


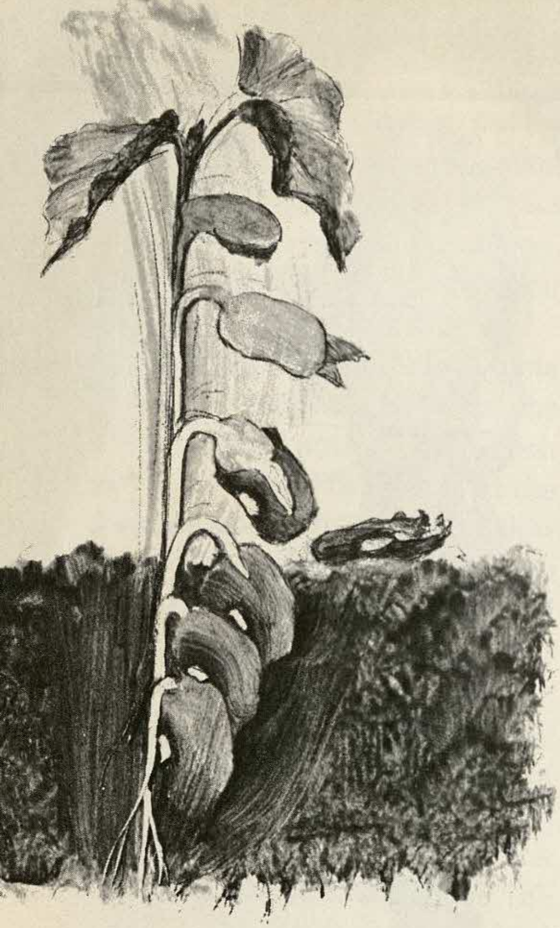
Measuring Plant Growth

Growth in plants is often easy to measure, even though such growth is usually too slow for us to observe without special instruments. Parts of some plants grow rapidly. Bamboo stems grow as much as two feet per day. Mushrooms spring up overnight. Scientists measure the growth of different parts of a plant and then try to find out what makes the plant grow faster or slower.

The growth of some trees is especially easy to study because of annual growth rings. Perhaps you have examined the rings in a tree stump to find out the age of the tree when it was cut down. You can also tell the age of branches on a tree after you learn to identify the marks on them.

Look at the picture of a twig of a horse chestnut tree as it appears in winter. The bud at the tip of the twig is called the terminal bud. Can you guess what terminal means? The bud on the side is called the lateral bud. As soon as spring comes, the scales on buds like these begin to open up, and the new growth of stems or flowers appears. The scales remain at the base of the new growth. The distance from one bud scale scar to another is a year's growth. Examine a twig and find out how many years of growth are marked on it. You can also tell how many leaves were on the stem each year by counting the leaf scars.


Terminal bud
Lateral buds
Leaf scars
Holes where sap flowed into leaves
Scars made by last year's terminal bud
Lenticel



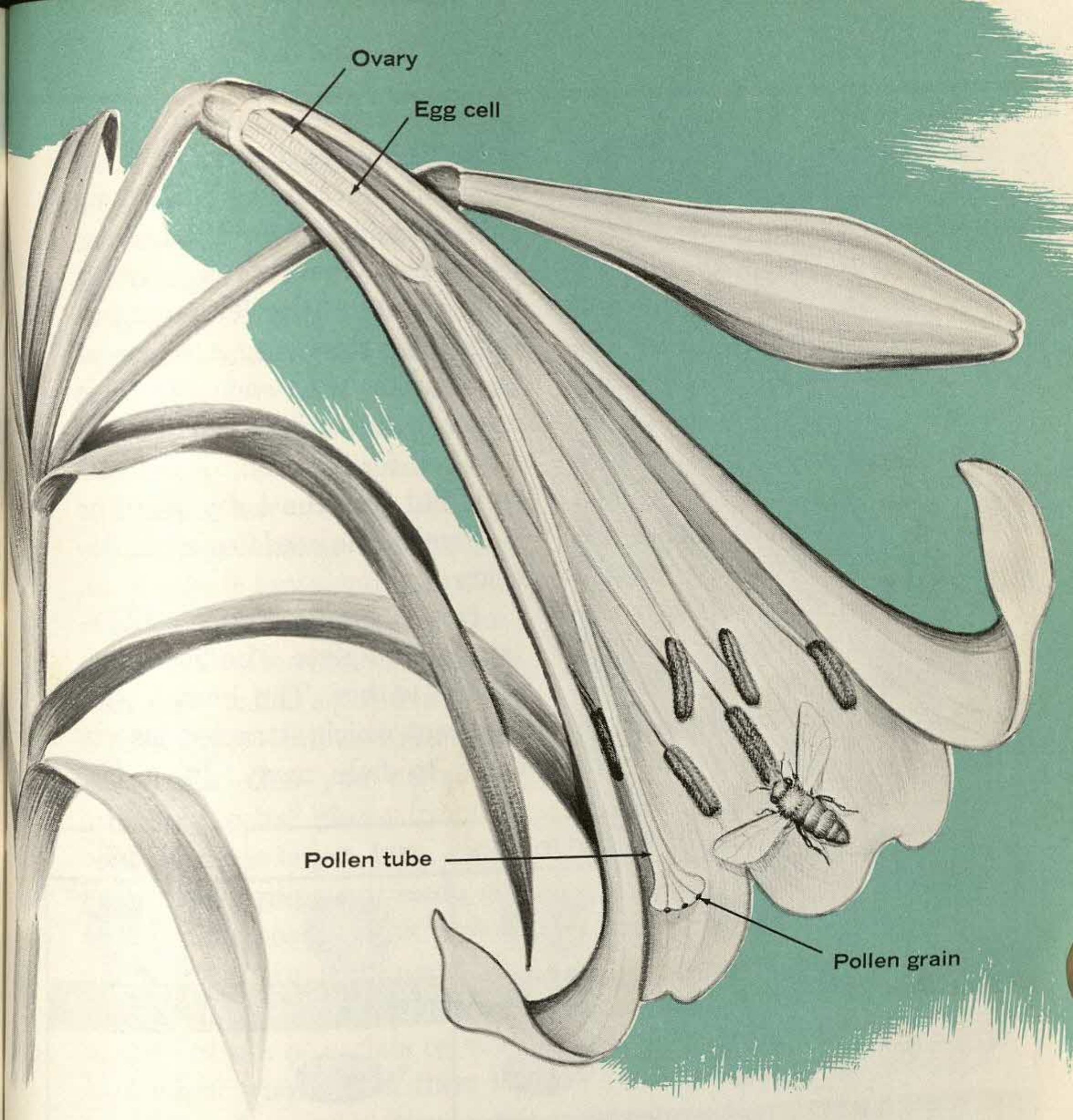
MEASURE Obtain a young plant that is about two or three inches high. Put a spot of red dye, paint, or fingernail polish on the stem of the plant an inch from the ground. Record the date. After the plant has grown several inches, measure the distance from the red spot to the ground. Has the growth taken place above or below the red mark? Make another red mark an inch from the ground. Record the date. Measure and record the distance between the two red marks. After the same interval of time has passed, measure the distance between the lower red mark and the ground. What is the distance now between the two red marks? What part of a young plant grows fastest? □□

There is another sign of growth in plants that scientists have only begun to study. They have noticed that as a plant grows, the leaf on the stem changes in size and shape. Compare a young sprig of coleus with an older one. Do you see any difference in the shape of the leaves? Select a plant for study. Carefully make a tracing of a leaf. At intervals of one week, make other tracings of the same leaf. Can you discover any difference?

Some Plants Reproduce from Seeds

Plants can reproduce in a variety of ways. In most of the plants you know, flowers are the special organs for reproduction. An examination of the different parts of an Easter lily will help us understand this process of reproduction.

Both male and female organs are necessary for reproduction in flowering plants. Because one Easter lily has both male and female organs, we say it is a "complete flower." The male organ, or stamen, produces a powdery sub-



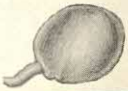
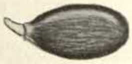
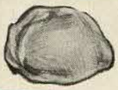
stance called pollen. The female organ necessary for reproduction is called an ovary. The ovary is at the bulging base of a long slender tube, the style. The sticky surface at the top of the style is the stigma. The ovary, the style, and the stigma make up the part of the plant called the pistil.

Remove the stamens of an Easter lily and you will see the pistil, which looks like a slender vase. When a pollen grain from a plant is brought to the pistil of a plant of the same kind, this action is called pollination. How do you think pollen might be brought to the pistil?

You have seen bees and other insects frequently visiting flowers. Did you know that these insects help the flowers to reproduce? The beautiful colors and the fragrant scents of flowers attract the insects. A bee works its way deep down inside a flower to get at the nectar lying in the glands of the flower. As the bee does this, its fuzzy little body is covered with pollen. What happens when the bee gets to the next flower? Bees visit the same kind of flower during any one working day. What advantage is this to the flower? Would pollen from an apple blossom pollinate a peach tree?

After the pollen is rubbed off onto the stigma, the pollen grain grows down through the long tube of the pistil until it reaches the ovary. There are sperm cells in the pollen tube. These sperm cells enter the ovary and one of them unites with each egg. This union of the sperm and the egg is called fertilization. From the fertilized egg, the baby plant or embryo in the seed begins to develop.

Now pollination and fertilization are complete. The flower begins to wither. The beauty and the scent which attracted insects begin to fade away. In a few

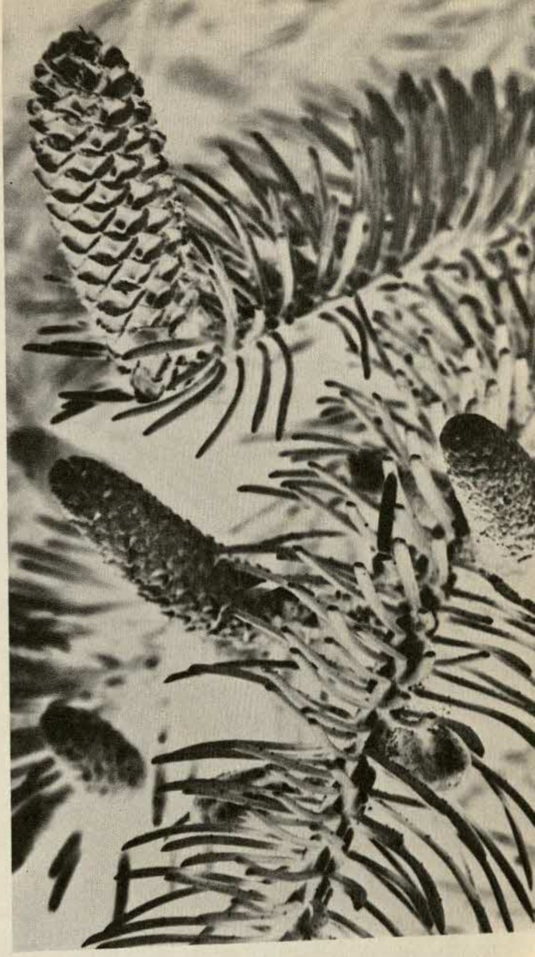
Seeds	1st Day	2nd Day	3rd Day	4th Day
Pea				
Watermelon				
Bean				
Grapefruit				
Cantaloupe				

more weeks or months, seeds will be ready to be scattered.

The seeds of flowering plants are carried within the ovary. A ripened ovary is called a fruit. It may surprise you to find out that tomatoes, cucumbers, and olives are fruits. The fruit protects and helps distribute the seed, which eventually becomes a new plant.

Fruits have many different structures. Because the ovary of an orange is large and pulpy, the orange is called a fleshy fruit. Bean seeds are carried in a long, thin ovary called a pod. Nuts have a hard ovary wall and are called dry fruits. Can you name any other dry fruits? Fleshy fruits?

Find some beans, peas, cantaloupe seeds, grapefruit seeds, and watermelon seeds. Soak several different kinds of seeds overnight. Put them on moist paper or cotton in the bottom of a glass or bowl. You might want to put them between the glass and blotter so you can see them better as they grow. Keep the paper or cotton moist while the seeds are germinating and then growing. Make a chart showing the time it takes each little plant to push out of the seed and begin to grow. What provides food for the developing seedlings? What must you do to keep these seedlings alive?



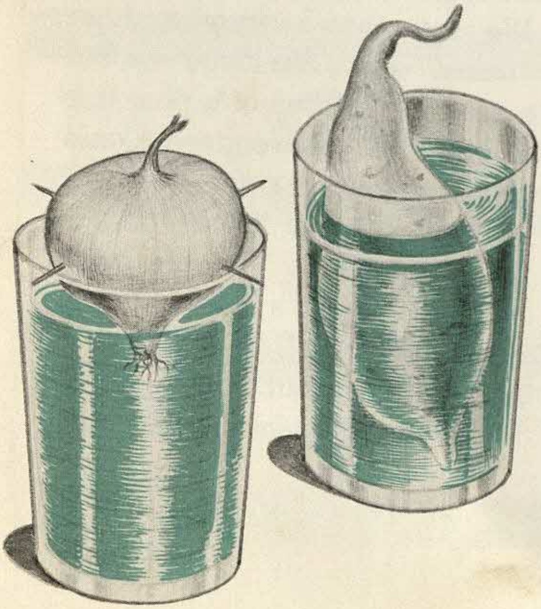
Evergreen trees produce seeds that are not covered by an ovary. These seeds are produced in cones. We say that evergreens have "naked" seeds. See if you can find a seed in the cone of a pine tree or other kind of evergreen. Cones on evergreens serve almost the same purpose as flowers on the flowering plants. The life cycle of a pine tree is a long and very interesting one. Go to the library and try to find out more information about the pine tree.

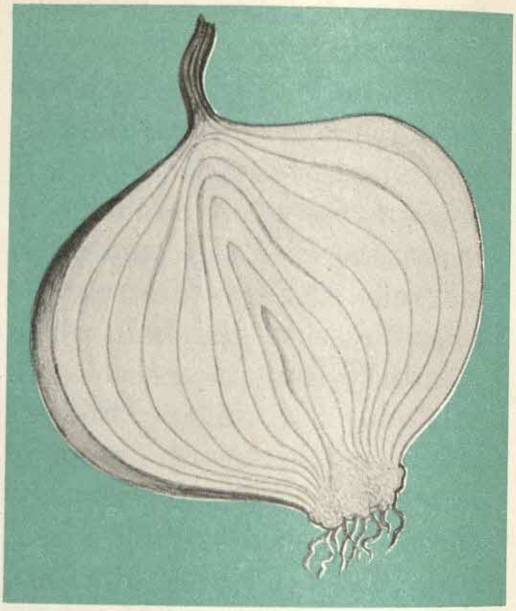
Some Plants Reproduce from Stems and Roots

Have you ever seen your mother start a new plant by cutting a leaf from a plant and putting the stem in water? How long does it take before roots start to grow from the stem? After roots have developed, will the leaf grow into a new plant if it is placed in soil? If you have not seen this kind of reproduction, try it with a coleus or geranium leaf.

You have already grown plants from one kind of underground stem. What was it? The bulbs of tulips, daffodils, and onions are also special underground stems.

DESCRIBE Put four toothpicks in the side of an onion. Prop the onion over a glass of water so that the base of the onion is in the water. In a short time roots and stems will appear.





Cut another onion in half, lengthwise. Look at the bud in the center. Tightly packed leaves around the bud contain stored food. If you leave an onion on the table for a few weeks, the onion will begin to grow. Explain. ☐☐

A sweet potato is part of a root. It is interesting to grow a sweet potato vine.

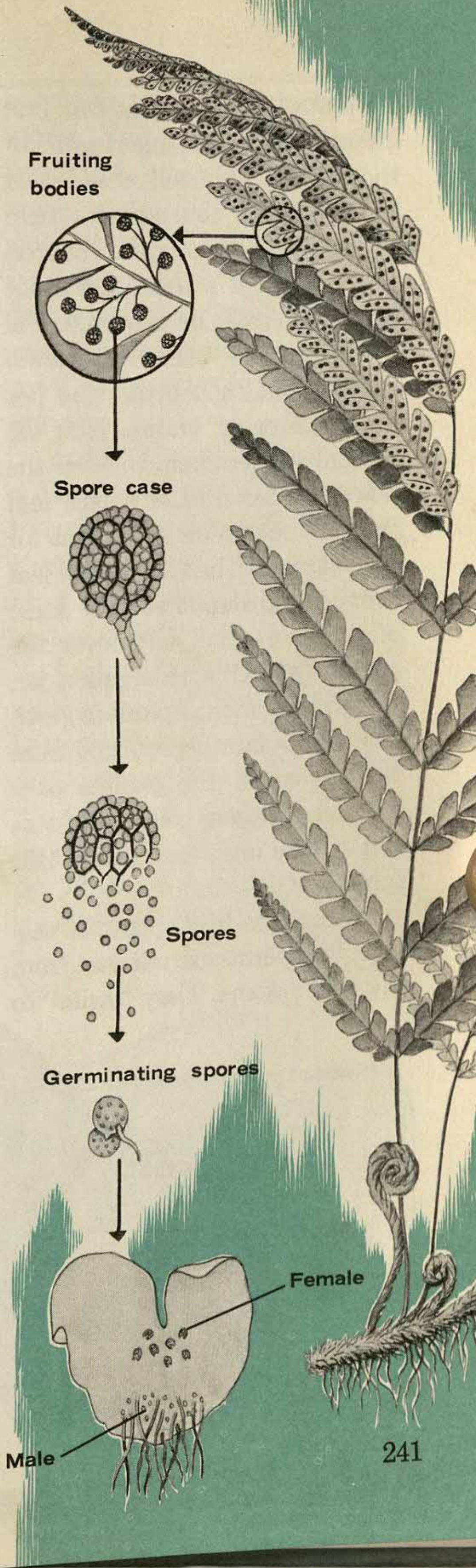
OBSERVE Put the pointed end of a sweet potato into a glass of water. Which appear first, roots or stems? ☐☐

Some plants stay alive from year to year by storing food in underground roots or stems. If a carrot is left in the ground throughout the winter, its leaves die and the plant appears dead above ground. In the spring, a new stem, leaves, and flowers appear. These flowers produce seeds. During the following summer, new carrots grow from these seeds.

Some Plants Reproduce by Spores

Ferns have two means of reproducing, both of which are necessary to produce new fern plants. During part of the fern's life cycle, the plant is smaller than your little fingernail. This tiny plant is formed from reproductive cells called spores, which the fern plant produced. It is not very much like the plant you know as a fern.

The fern plant you have seen in flowerpots or in the woods is made up of long leaves that grow from an underground stem. What is an underground stem called? The fern leaf is made up of many small leaflets. The whole leaf is known as a frond. Some of these fronds may grow very tall. In fact, some ferns may grow as high as forty feet. In the late summer or early fall you may find a fern plant with dusty brown spots on the underside of the leaflets. These are fruiting bodies or sori (SO-ree). Within the sori are spore cases, called sporangia (spuh-RAN-jee-uh). When the sporangia burst open, spores are released.



DISCOVER If you can find a fern with spores, plant some of the spores. You will need moist soil and a dark, cool place for them to germinate. If you plant them on the outside of a moist flowerpot they can easily be observed. Fill the flowerpot with wet newspapers, and then invert the pot in a saucer of water. How do the newspapers help to keep the flowerpot moist? Let a fern leaf that has spores on it dry out for several days. Then shake the leaf over the flowerpot so that some of the spores fall off; cover the pot and saucer with a gallon jar. Watch for the small plant to grow. This little plant is produced from the spores on the leaflets of a fern frond. Organs containing eggs and sperms are produced on this tiny plant.

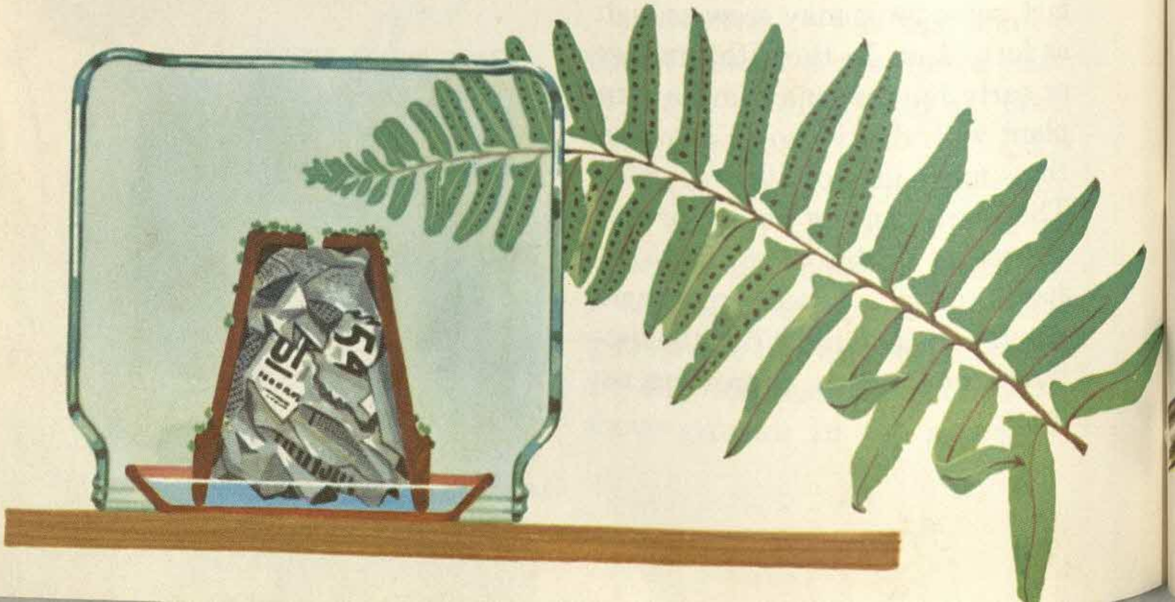
When the little plant is mature, the sperms are released from the male organs. They "swim" to the egg, and fertilization takes place. Just as in the seed plant, a new plant can grow from the fertilized egg. This new plant will be the plant you know as a fern.

Plants That Do Not Produce Seeds

There are many kinds of plants that never produce seeds. We will study only a few of them.

Have you ever seen shelf-like growths on tree trunks like those shown in the picture? These plants belong to a large group of plants called fungi (FUN-jy). Fungi contain no chlorophyll, so of course they cannot manufacture their own food. All fungi grow on other materials that are alive or were alive at one time. How do fungi get nourishment?

One of the most familiar fungi is the mushroom. Fungi produce spores, which you may be able to observe.

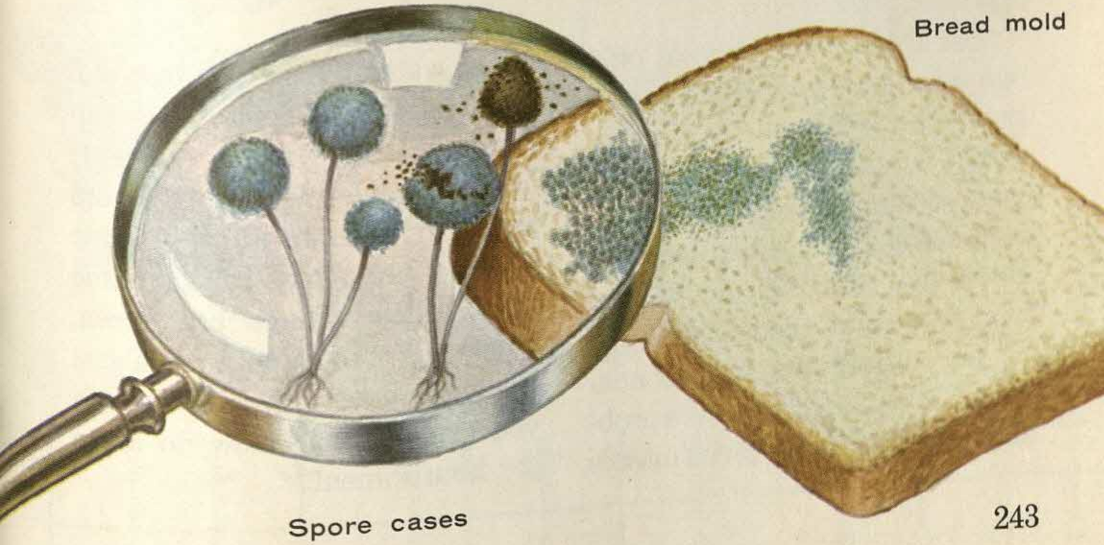


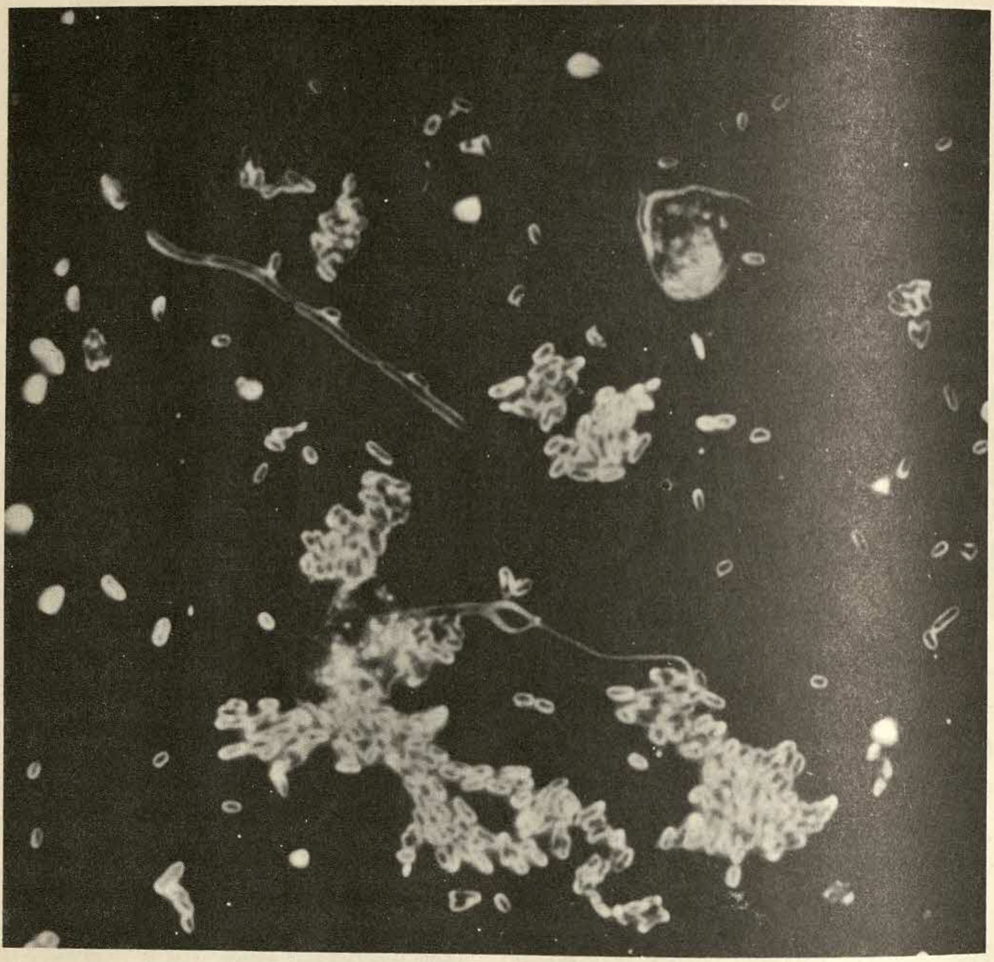
EXPLORE If you can find a mature, fresh mushroom, break off the stem and turn the cap downward on a sheet of dark paper. Are there many spores? Why do you think there are so many?

You can grow a kind of fungus, called bread mold, to find out more about reproduction by spores. You have probably seen spores on a spoiled orange or moldy bread. If you blow on the mold when it is mature, you will see a cloud of dust in the air. This dust is made up of millions of little spores. These spores are so numerous that there are always some in the air.

ACTIVITY Moisten a piece of bread, and put it in a saucer. Put the saucer in a dark place. Keep the bread moistened, and after a few days mold will appear on the bread.

Look at the mold with a magnifying glass. The small round balls on the end of the slender stalks are the sporangia. When the sporangia are ripe, they release all of their spores into the air. Some spores fall down on the bread to form new mold. □□





Rod-shaped bacteria found in water

Some fungi are made of only one cell, which is so small that it cannot be seen without a microscope. These one-celled plants are called bacteria. Bacterial cells reproduce by dividing into two cells. These two cells then divide into four, then eight, then sixteen, etc.

If you have ever walked near a pond in summer, you have probably noticed floating green masses in the water. This green material is a plant which belongs to a group of plants called algae (AL-jee). Most algae live in the water. There are many different kinds of algae — some are single-celled, some many-celled. There are green, blue-green, brown, and red algae. All algae have chlorophyll. Can you explain this? How do algae get nourishment?

Life Cycles

Annuals, Biennials, and Perennials

Plants may be grouped according to their life cycles.

Plants that live for only one season are called annuals. The seeds of annuals must be planted every spring. Petunias, snapdragons, larkspur, and tomatoes are all annuals. Can you name others? Annuals are good garden plants because they grow rapidly.

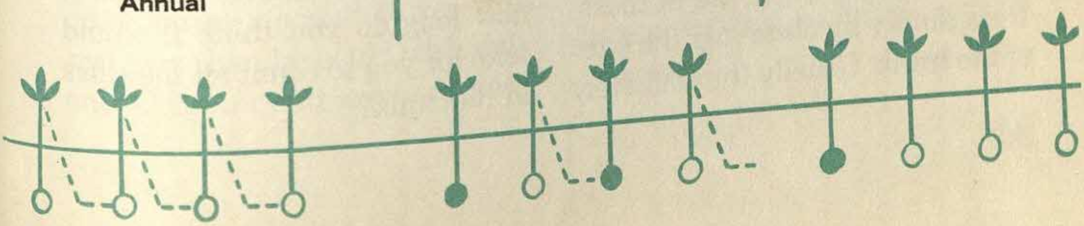
The carrot takes two years to complete its life cycle. Such a plant is called a biennial (by-EN-ih-al). Find out about the life cycles of beets, parsnips, sweet Williams, hollyhocks, and forget-me-nots.

There are many plants which grow more than two growing seasons. These plants are called perennials (pur-EN-ih-'lz). Perennials die back to ground level each fall. The roots live underground from year to year. Irises, poppies, chrysanthemums, and day lilies are perennials. These make good garden flowers, because they will come up each year without being replanted. Can you name any others?

Annual

Biennial

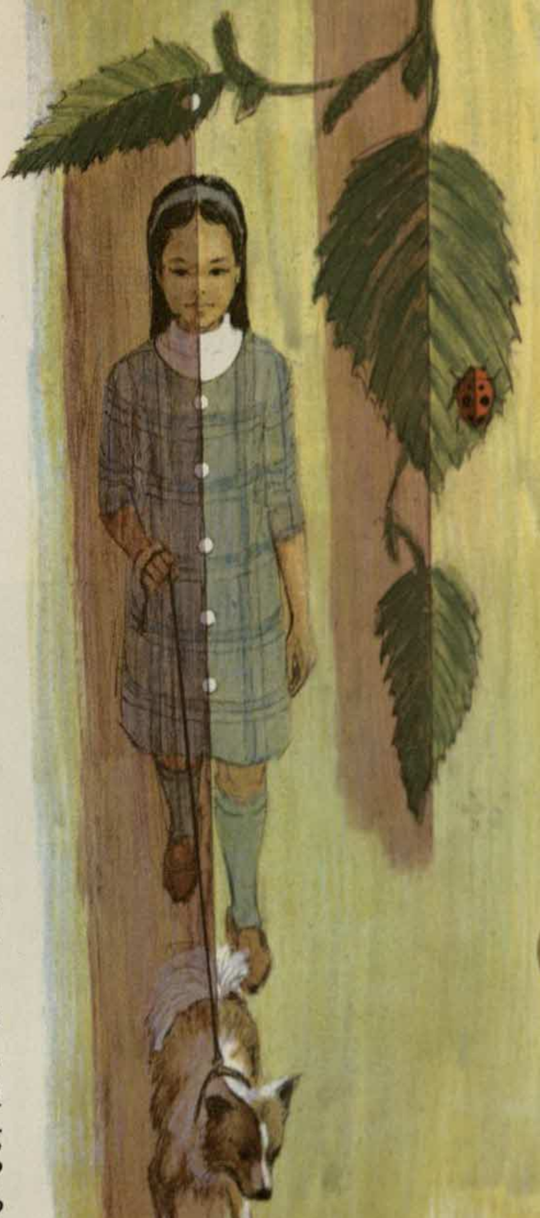
Perennial



The Oldest Living Things

Some trees are the oldest living things on earth. We can tell something about the age of most trees simply by observing the size of the trunk. Usually the diameter of the trunk indicates the age of the tree. One of the biggest giant redwood trees may be 3,400 years old. If this tree is ever cut down, how long do you think it would take for you to count all the rings in its trunk?

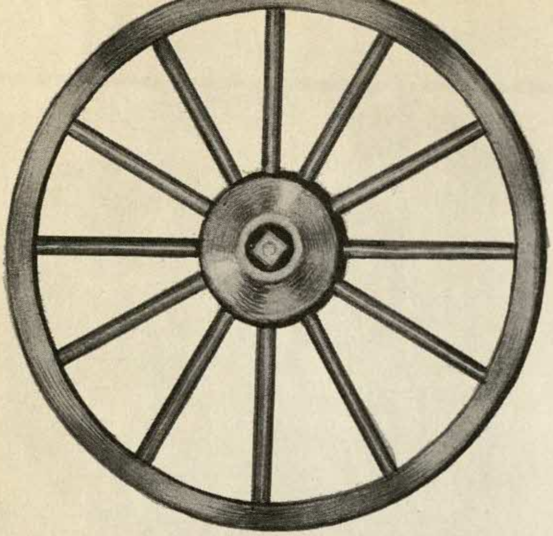
Basic Patterns in Living Things

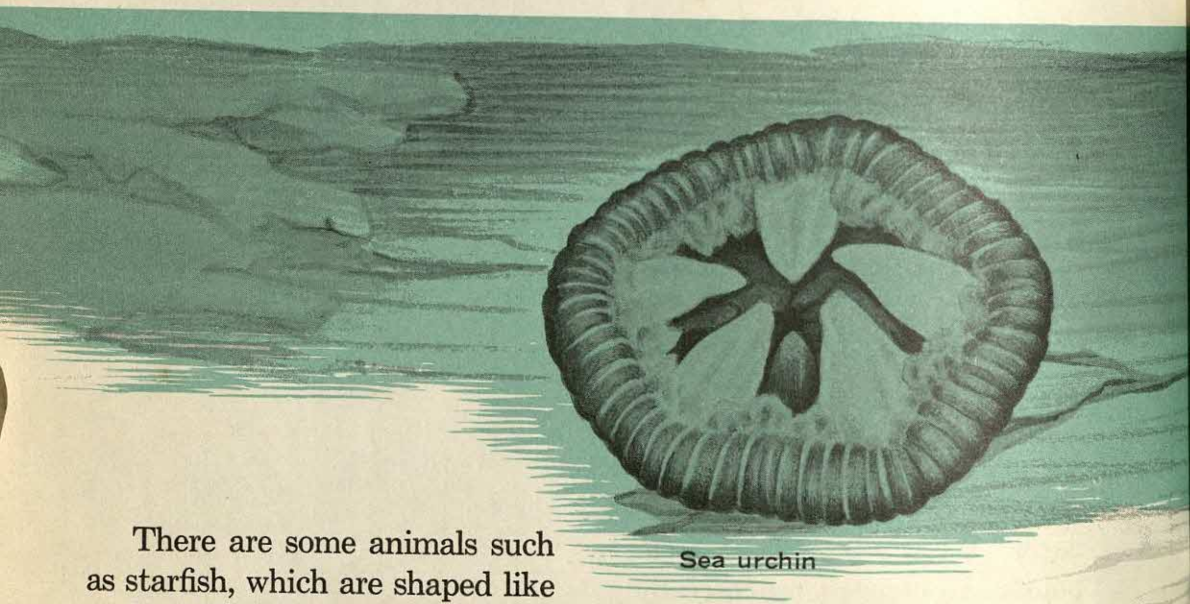


You have studied some of the different structures of animals and plants. These different structures enable animals and plants to stay alive and to perform the functions of moving, getting food, and reproducing. Have you noticed any similarities among all these different kinds of animals and plants? What are they?

What similarity of pattern do you notice in these pictures of living things? If you were to draw a line down the center of each of the living things pictured here, you would find that the parts on one side are like the parts on the other side. We call this pattern bilateral symmetry (SIM-uh-tree). Bi means "two" and lateral means "sided." Are you constructed similarly? What other animals and plants are constructed according to this pattern? A turkey gobbler? A honey bee? A bird? An orchid?

Can you think of any advantage in being bilaterally symmetrical? If a dog should lose the sight in one eye, he can see out of the other. A man can locate the direction of a sound better with two ears than he could with only one. Can you find leaves or flowers in which all the parts on one side are just like those on the other? Do you think plants have any advantage in being made in this way?





Sea urchin

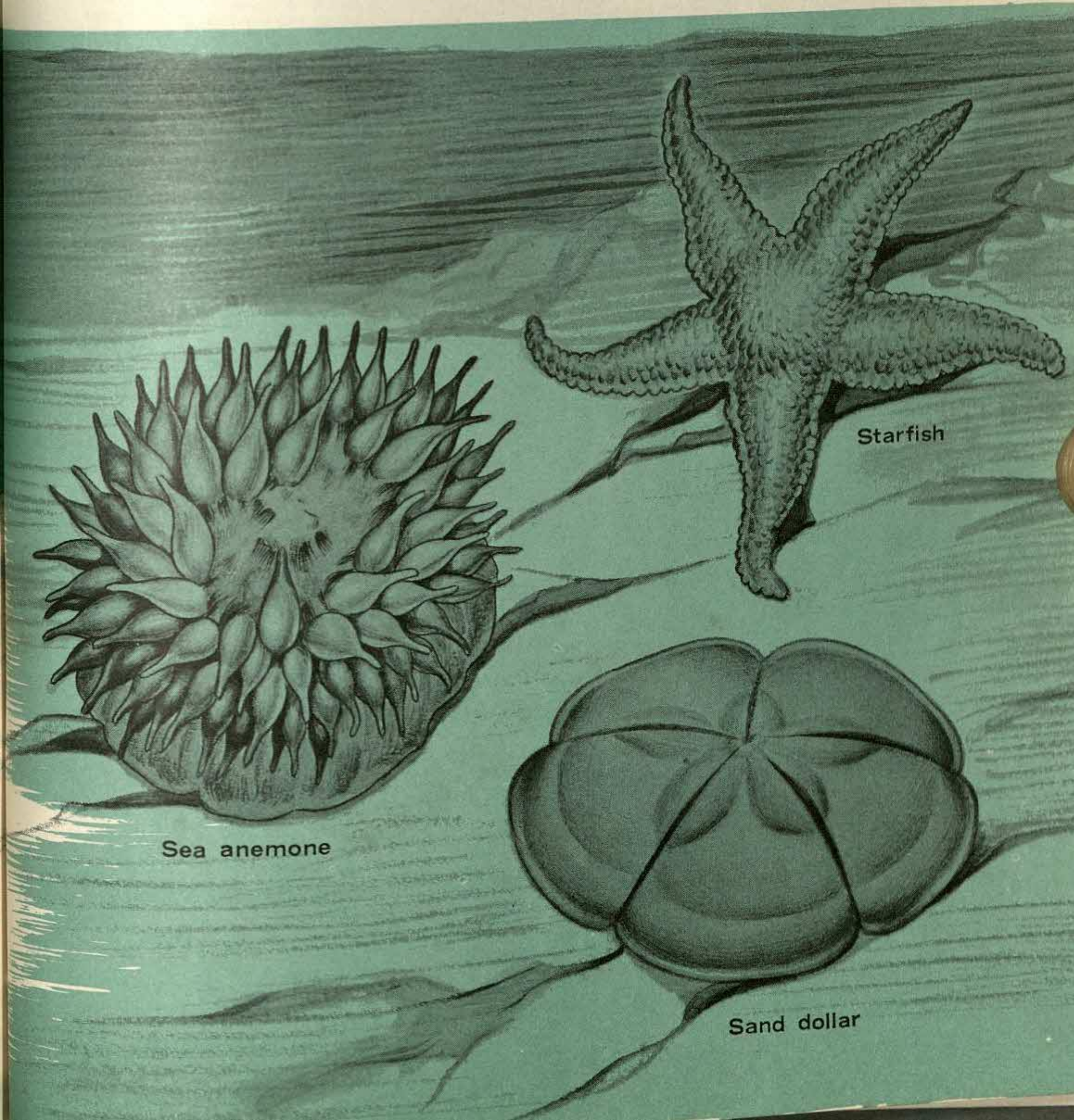
There are some animals such as starfish, which are shaped like a wheel. They have rays similar to the spokes of a wheel. Notice how the spokes of a wheel all come from the center and are all the same length. These spokes are called radii (RAY-dee-eye). The wheel is said to be radially symmetrical. Animals like the starfish are also radially symmetrical. Do you think the starfish has any advantage in being this shape? Have you ever seen a sand dollar or a sea anemone? What kind of symmetry do they have? What flowers are radially symmetrical?

Some animals, such as the amoeba, have no definite shape and are called asymmetrical.

Variations in Living Things

In this unit you may have thought more about the variations in animals and plants than about their similarities. Did you know that there are about 900,000 different species of animals? There are fewer different kinds of plants —only about 300,000! You have had time to study only a few of them and to learn only a little about some of their structures.

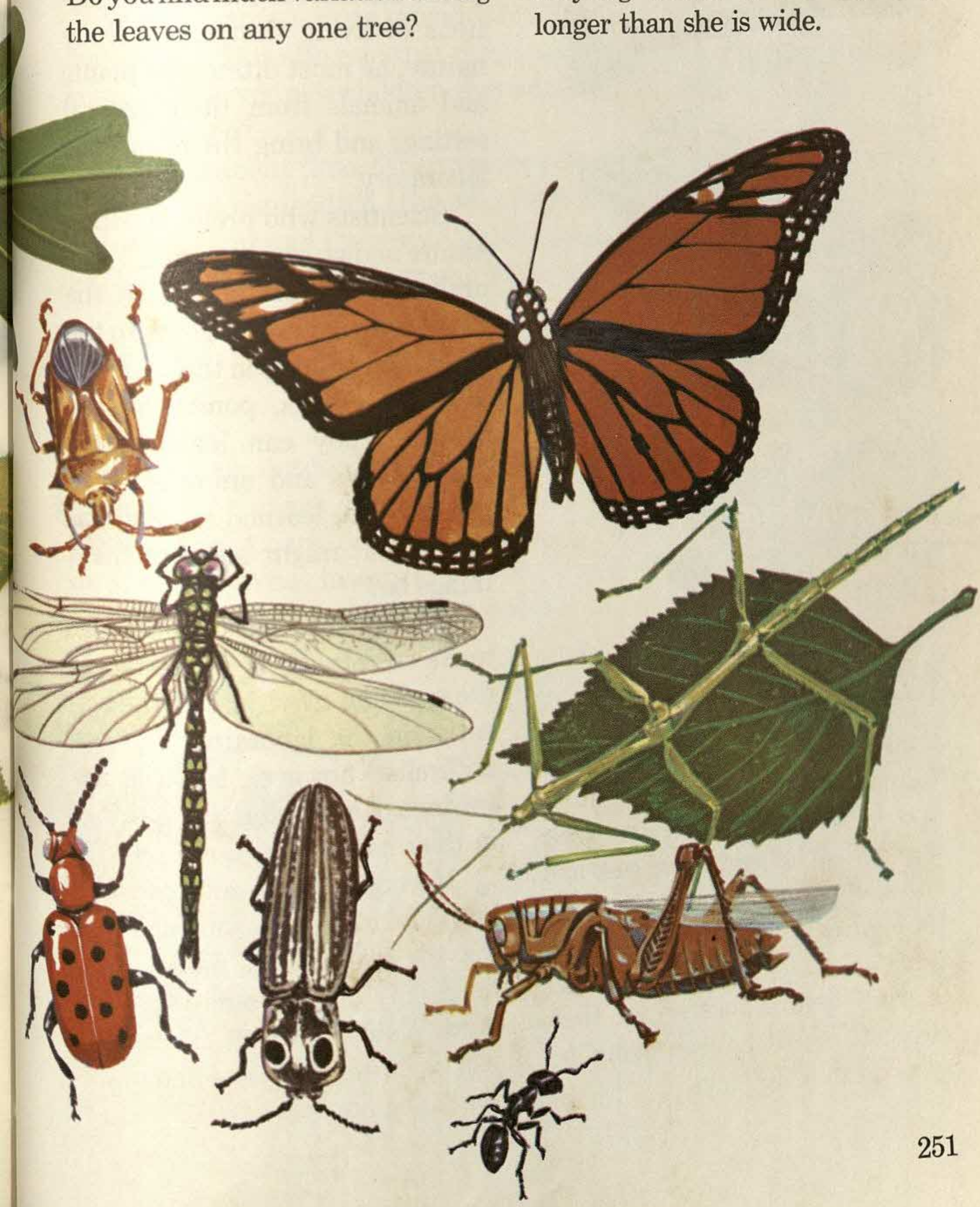
There is so much to be known about the animal and plant world. Many plants and animals have not even been named. Many more have received names, but we still do not know very much about them.

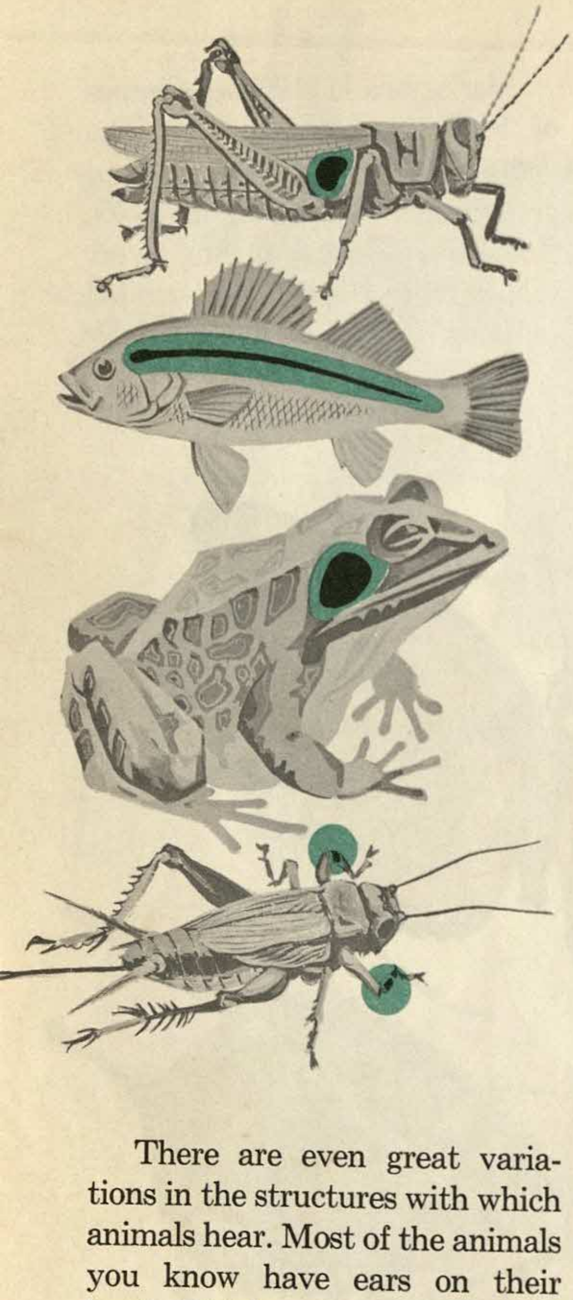


When Henri Fabre, a French scientist (1823-1915), was about your age, he began to collect and compare beetles. He observed grasshoppers with their short or long antennae, spiders in their lacy webs, weeds with their curious fruits and seeds, and trees with leaves of innumerable shapes and sizes.

Make a collection of leaves from different trees. Notice the interesting variations. Measure across the widest part of the leaves. Arrange them in order from the largest to the smallest. Do you find much variation among the leaves on any one tree?

Variations in the body shapes of insects are interesting. The walking stick has been given a good name, considering its looks. Some insects grow as long as six inches, while the chubby, rounded ladybug beetle is scarcely any longer than she is wide.





There are even great variations in the structures with which animals hear. Most of the animals you know have ears on their heads. Fish have internal ears and a hearing nerve along their bodies that is sensitive to sound vibrations. Some grasshoppers have hearing organs located in their sides. Crickets have hearing organs on their forelegs.

Studying Nature

Nature can be studied in many different ways. A scientist, studying nature, wants to learn about the various forms and functions of living things. To study nature, he must often take plants and animals from their natural settings and bring them into the laboratory.

Scientists who prefer to study nature undisturbed are called naturalists. Naturalists observe the many forms of life by going to the plants and animals in their natural settings — fields, ponds, forests, deserts. They can learn things about plants and animals which can never be learned in a laboratory. What might some of these things be?

As the naturalist probes nature's secrets, he is interested in the question *why*, just as the scientist in the laboratory is. The naturalist, however, has the advantage of observing living things in their natural surroundings.

If you, too, are interested in both looking for reasons and seeing the beauties of nature, you need only go to your own back yard. Watch and wait. There you will begin to discover some of nature's secrets.

THINK

Most communities are concerned about forest fires and grass fires. Describe or show the effect of a forest fire on animals, plants and their relationships.

Why is soil conservation important to the city dweller as well as to the person living on a farm?

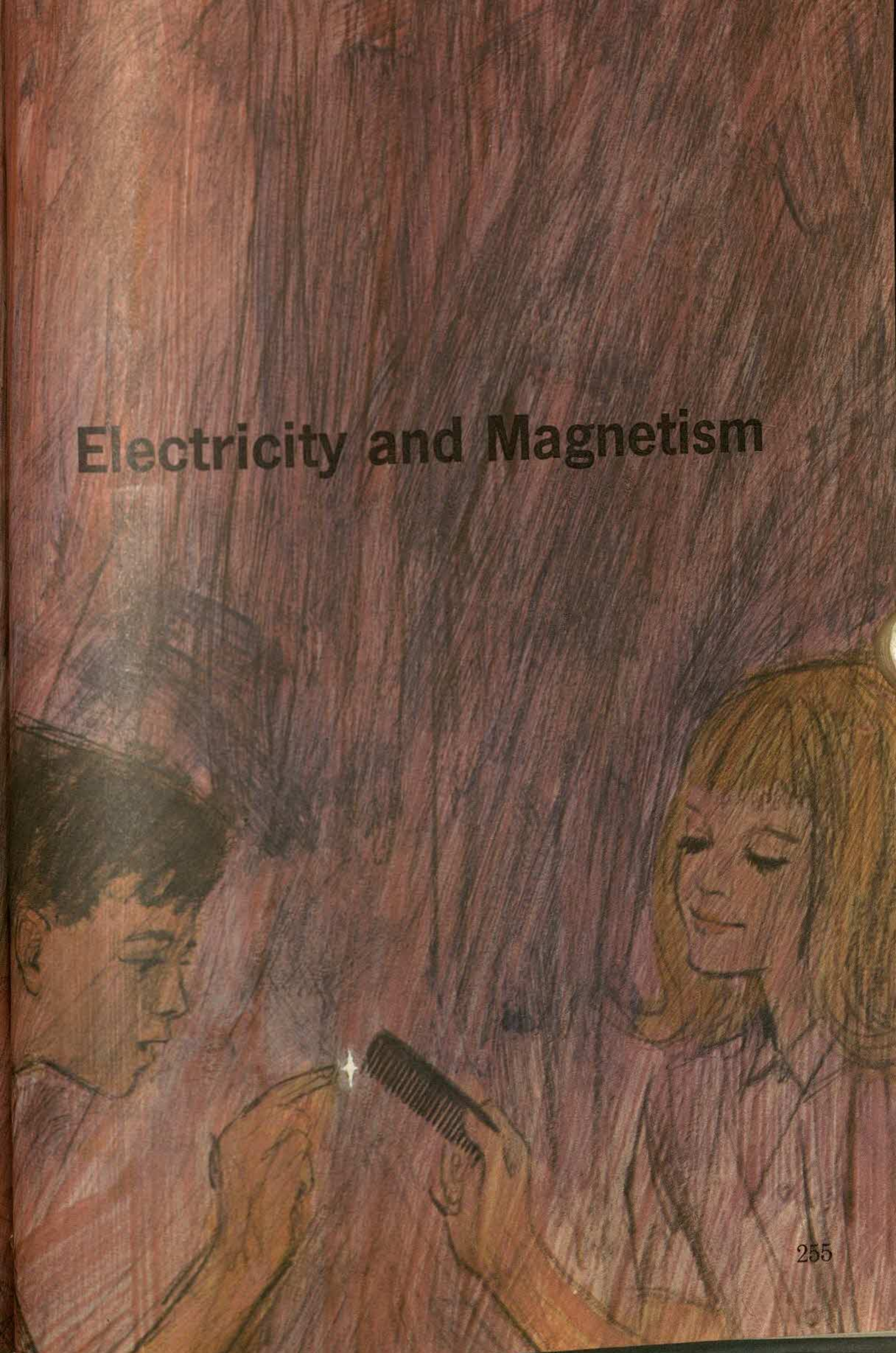
It is said that nature provides for the continuation of each type of living thing. It is also said that the greater the care parents give to their young, the fewer new children they will have. How are these two statements related?

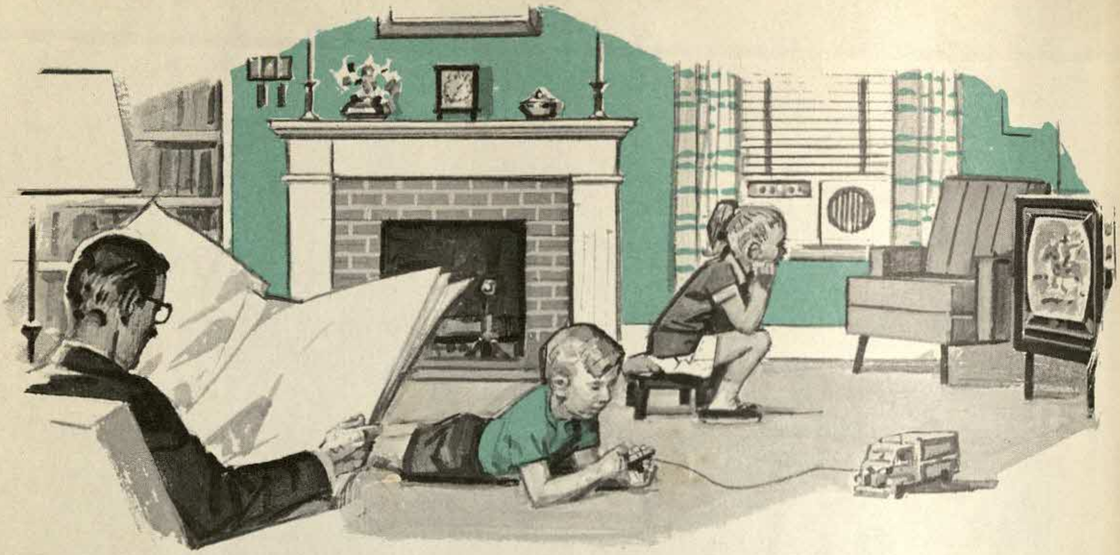
At the present time, fishermen are catching tons of a particular type of fish called manhedren. The oils of this fish are used to make clothing water repellent and the rest of the fish is used to make food for animals. Explain how this practice might be dangerous.

PROJECT

Explore an outdoor area where you can find a variety of plants and animals. You might examine plant and animal life in an open field, a wooded area, a park, or your backyard. What flowers, grasses, and trees do you find? What insects and birds do you find? How could you help the growth of living things in this area?

Electricity and Magnetism





The Importance of Electricity

How many objects in the living room depend upon electric current to operate? Name the objects in the bedroom that require an electric current to operate. Look at the kitchen. What energy transformations take place in the toaster? How many of the appliances supply useful heat energy? Which appliances use electrical energy to preserve and prepare your food? How does electricity help to keep your clothes and your home clean? Through what electrical machines is the temperature of your home kept at a comfortable degree? In how many ways can electricity provide entertainment for you in your home?

The answers to all these questions must convince you that electrical energy is very important in your daily life. What is the source of electrical energy? How did man discover electrical energy? How long did it take him to learn to use it? You will learn the answers to these questions from the following activities and lessons.

Frictional Electricity

Have you ever heard a crackling sound as you stroked the fur of a cat or dog? Has your hair ever crackled as you brushed or combed it? Have you felt a tiny shock as you reached for a doorknob after shuffling your feet across a rug? Each of these occurrences involves two objects which rub against each other. A hand rubbing the fur of an animal, a brush or comb rubbing against hair, and shoes rubbing across a rug are examples of friction. When objects rub against each other, there is friction.

DISCOVER Cut some newspaper into very small pieces, and set them on a table or on your desk. Bring a hard rubber comb near the pieces of paper. What happens? Rub the comb on some woolen cloth, or comb through your hair a few times. Now bring the comb near the pieces of paper again. What difference did rubbing the comb make? For the best results, do these activities in cool, dry weather. Rub the comb again. Rub harder and longer than before. Is there any difference in what happens when you bring the comb near the pieces of paper? □□

About 2,500 years ago, the Greeks were aware of the attraction between a rubbed object and lightweight bits of materials. Thales (THAY-leez) of Miletus in Greece discovered that a yellow stone, called amber, crackled and gave off sparks when it was rubbed with fur or wool. It attracted, as if by magic, tiny bits of feathers, dried leaves, and pieces of straw. Thales used this discovery to entertain his friends.

Bring a glass rod or a plastic toothbrush container near the pieces of paper. What happens? Rub the glass rod or plastic container briskly with a silk kerchief. What happens now if you bring the rubbed object near the pieces of paper? To get good results be sure your hands are dry.

Some 2,000 years after Thales' discovery, Sir William Gilbert (1540-1603), physician to Queen Elizabeth I of England, studied friction. He found there were other substances which, when rubbed, attracted light pieces of paper, feathers, and cloth. Gilbert also discovered that substances

other than wool or fur could be used for the rubbing. It was Gilbert who applied the word "electricity" to this attraction between some rubbed materials. Electricity comes from the Greek word "elektron," which means amber. Objects which have been rubbed and so attract light objects are said to be electrified.

The electricity which resulted from rubbing two materials together is called frictional (FRIK-sh'n-'l) electricity. Charles du Fay of France (1698-1739) found in his experiments that there seemed to be two kinds of frictional electricity. There was the kind found on amber or sealing wax when it was rubbed with wool. There was another kind found on glass when it was rubbed with silk.

Kinds of Charge

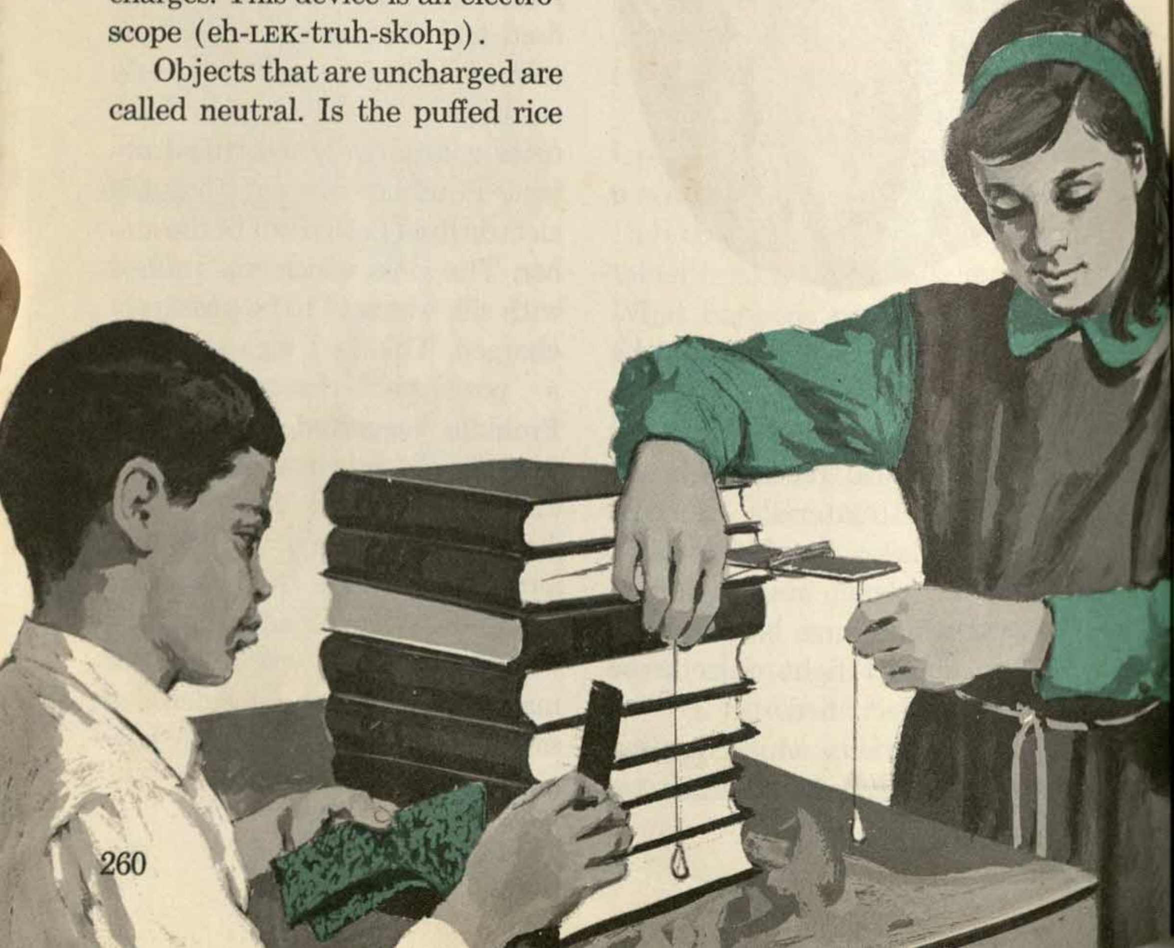
The first great American scientist, Benjamin Franklin (1706-1790), called the two kinds of electricity positive and negative. He suggested that electricity was a fluid and that amber which was rubbed with wool was negatively electrified. The (−) sign indicates a negatively electrified object. Franklin thought that the electric fluid flowed out of the amber. The glass which was rubbed with silk was said to be positively charged. The (+) sign indicates a positively charged object. Franklin suggested that electric fluid flowed into the glass. So it was thought that electric fluid flowed from an object which had more of it to one that had less. Franklin's idea about electricity was later proved wrong, but for many years it was considered a satisfactory explanation of how electrified objects react.

Using an Electroscope

IDENTIFY Wind a piece of silk thread around the end of a ruler, allowing about eight inches to hang free from both sides. Support the ruler as shown in the picture. Thread a needle with one end of the thread. Stick the needle through a piece of puffed rice. (Do not use sugar-coated cereal.) Pull the thread through the cereal. Remove the needle. Tie a knot in the end of the thread. Fasten a piece of cereal to the other end of the thread. With this device you will be able to detect and identify charges. This device is an electroscope (eh-LEK-truh-skohp).

Objects that are uncharged are called neutral. Is the puffed rice charged or neutral? Charge your comb with a piece of wool. What kind of charge does it have? Bring it near the puffed rice.

How long does the puffed rice cling to the comb? Charging an object by touching it to a charged one is called charging by transfer. What charge does the puffed rice have now? When you charge by transfer, both objects will end up with the same charge. Once the pieces of puffed rice jump away from the comb, what is their reaction when you again move the comb close to them?



What is the reaction between a negatively charged body and a neutral one? What is the reaction between two bodies that are charged negatively? Check what you observed by repeating the activity.

Law of Charges

Making a charged object neutral is called discharging. You can discharge your electroscope by touching it. Discharge your electroscope.

ACTIVITY Charge a glass rod or a plastic toothbrush container with a silk cloth. What is the charge on the rod? Bring it near the neutral electroscope. What happens? Is the reaction similar to or different from the reaction with the negatively charged comb? What charge does the electroscope now have? Observe the reaction between the charged glass rod and the charged electroscope. Compare this with the reaction between the charged glass rod and the neutral electroscope. Note the reaction between the two charged pieces of puffed rice. What is the reaction between a positively charged body and a neutral one? What is the reaction between two bodies that are charged positively?

Discharge the electroscope again. Hold the two pieces of puffed rice by their threads about four inches apart while you charge them. Charge one of the pieces negatively. Charge the other piece positively. Return the pieces of puffed rice to their original positions. What is the reaction between the oppositely charged pieces of puffed rice? Repeat this part of the activity. Do you get the same results? What do you conclude? □□

Your experiences with an electroscope should help you to answer the following questions.

1. Is there any evident reaction between two neutral objects?
2. Is there an attraction between a neutral object and a charged one?
3. Is there a repulsion between two objects which are charged positively and between two objects which are charged negatively?

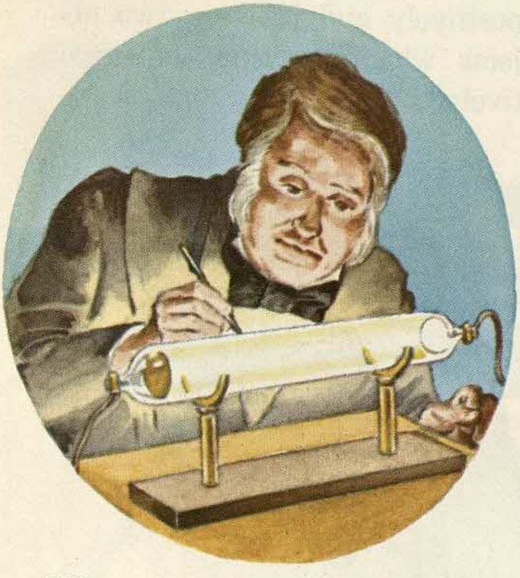
4. Is there an attraction between a positively charged object and a negatively charged one?

The answers to these questions can be summarized briefly: like charges repel; unlike charges attract. This statement is sometimes referred to as the Law of Charges.

Electron—The Moving Charge

We do not understand everything about electric charges. It has taken the experimental findings of many men from 600 B.C. to the present to learn what is known so far about electricity.

In 1854 a German glass-blower named Heinrich Geissler had invented a vacuum pump with which he could remove air from glass tubes in which he had put two metal strips. When an electric discharge was sent between the metal strips, a green glow was seen on the wall of the tube opposite the negative strip. What caused this glow? Some scientists said the glow was a kind of radiation like light or heat; others said it was a stream of particles of some kind. Forty-three years later, in 1897, Joseph John Thomson of England gave evidence that the glow was caused by particles. These particles were extremely small and were negatively charged. The word "electron" was suggested for these tiny negatively charged particles. To what does the word "electron" refer? How did Thomson's idea help us to understand electric charges?



You made electrons move from the wool to your comb. How did you do it? Rubbing causes friction between two surfaces. According to Thomson's idea, friction "rubs off" electrons from one surface to another. An object which has an excess of electrons is negatively charged. The comb is negatively charged. The wool is left with fewer electrons. An object which has a deficiency of electrons is charged positively. The wool is positively charged.

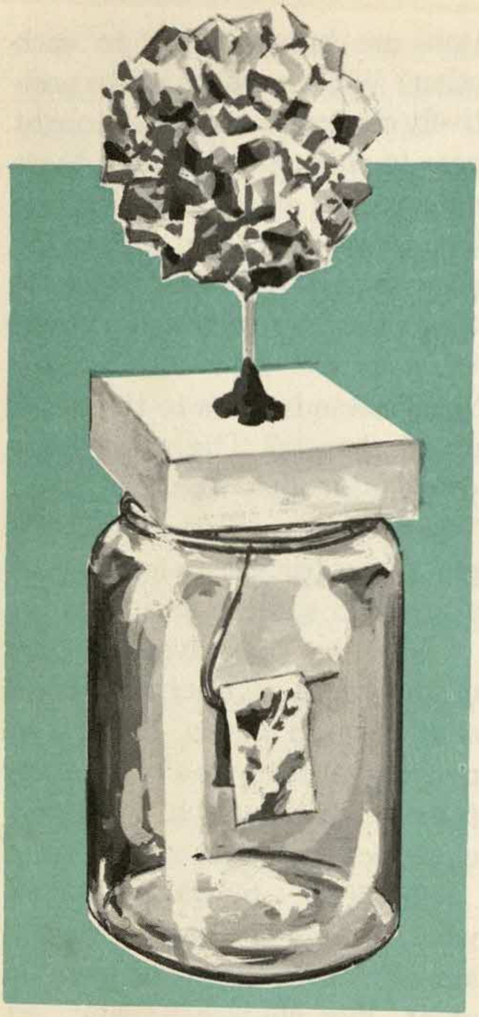
Balancing Charges

What makes the electrons move from an object that is negatively charged to an object that is positively charged? In nature, there is a constant tendency to establish and keep a balance. Electrons tend to move from an object which has an excess of electrons to an object which has a deficiency of electrons.

Now consider your experiences with the electroscope. What happens when two neutral bodies are brought near to each other? Why? What happens when a neutral body and a charged one are brought near to each other? Why are they attracted to each other? If the charged body is negative, in which direction do the electrons flow? If the charged body is positive, in which direction do the electrons flow? What happens when two negatively charged objects are brought near to each other? What happens if two positively charged objects are brought near to each other? Why is there no force of attraction? Why do the pieces of puffed rice jump away from the charged object to which they are attracted at first? What is the Law of Charges? What name is given to the build-up of charges? The word static (STAT-ik) comes from the Latin "stare," meaning to stand. Explain why frictional electricity is also called static electricity.

Now that you have some idea of the cause of electric charges and ways to detect them, you might want to make a better electroscope with which to detect electrification of other objects.

OBSERVE Select two puffed wheat grains of about the same size. Put a thin coat of metallic paint, like aluminum paint, on each. To do this neatly, use a pin to hold the grain. When you are finished painting the grain, stick the pin into modeling clay until the grain dries. Take one thread of copper wire from an old lamp cord, and thread your two metallic-coated puffed wheat grains with it so that they are about two inches apart. Take a glass pint jar and a stiff piece of copper wire that is twice the height of the jar. Bend



the end of the copper wire into a hook, and wind the copper strand around the hook once. This winding will hold the grains in place. Insert the other end of the stiff copper wire through a lid of waxed cork or paraffin big enough to cover the jar. Put the lid on the glass jar, and move the wire up and down until the grains are free to move without touching the sides of the glass. Use sealing wax to seal the wire in the lid. Wind the rest of the wire into a coil about two inches above the lid. Cover the coil with aluminum foil so a ball is formed.

Charge a comb. Touch the aluminum ball with the charged comb. What happens when you do this? How is your electroscope charged? Rub other pieces of material, and bring them *near* the ball at the top of the eletcroscope. What happens? What kind of charge is it if the grains separate more? If they close? What materials can you charge? How are they charged? Keep a record of your observations.

Substitute a thin piece of aluminum foil across the hook. Is it easier to detect a charge?

Charge your electroscope, and leave it in your room. How long does it keep its charge? On what kind of day does the charge leak faster?

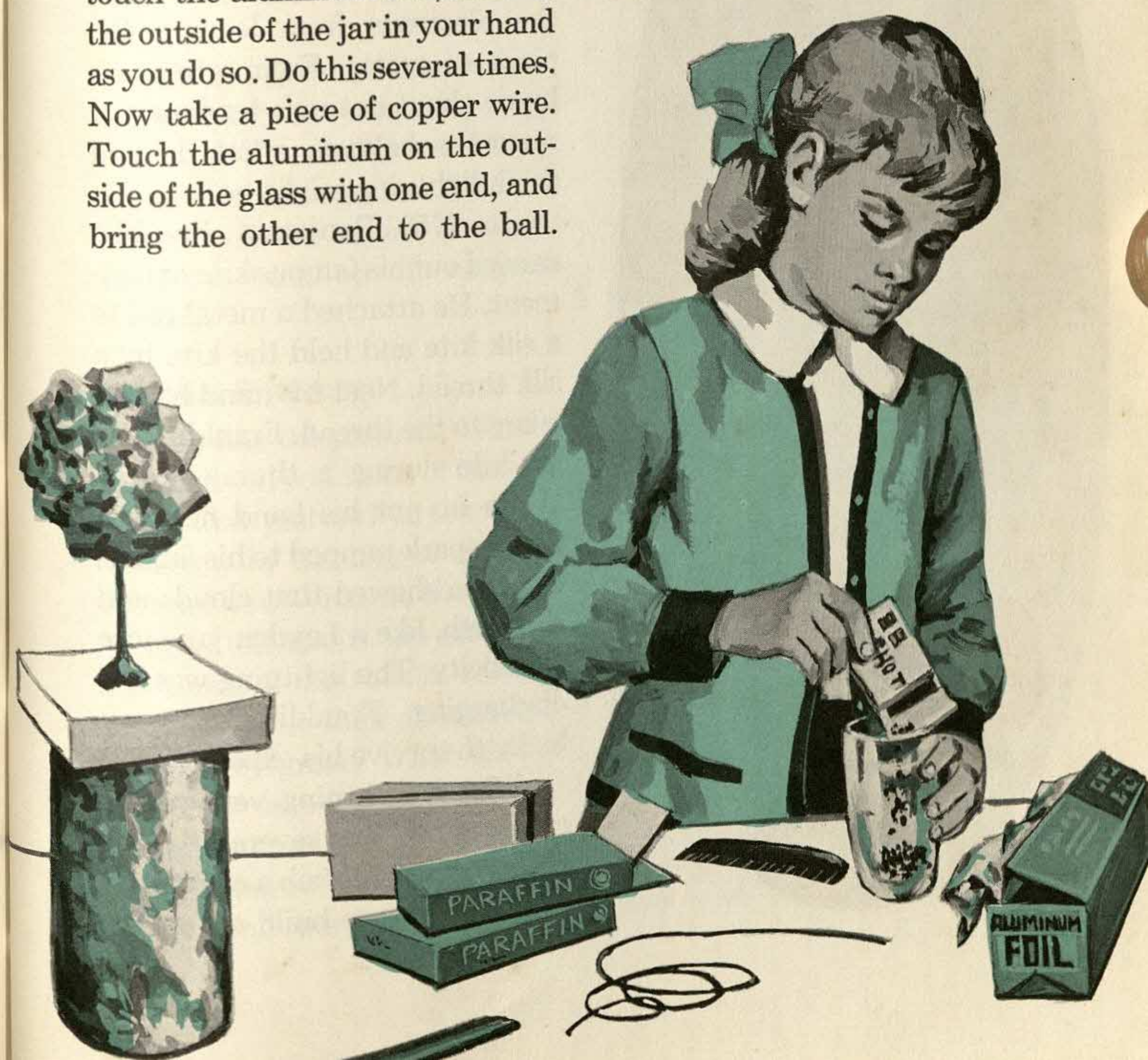
Watch your electroscope during a thunder and lightning storm. What do you notice? Compare your observations with those of your classmates.

Storing Static Electricity

DISCOVER Static electricity can be stored. Take a small glass, and cover the outside with a layer of aluminum paint or aluminum foil. Fill the glass to the depth of one inch with lead shot. If you don't have any lead shot, salt water will do. Cut a piece of paraffin to be the cover of the glass. Look at the picture. Insert a piece of copper wire through the lid into the lead shot. Seal the hole in the lid with sealing wax. Make a coil of wire at the top about two inches above the lid. Cover the coil of wire with aluminum foil so a ball is formed. Charge your comb, and touch the aluminum ball, holding the outside of the jar in your hand as you do so. Do this several times. Now take a piece of copper wire. Touch the aluminum on the outside of the glass with one end, and bring the other end to the ball. What happens? The fact that static electricity can be stored was first learned in 1745 at the University of Leyden in Holland. For this reason the device is called a Leyden jar.

Electricity in the Sky

Charge your comb with frictional electricity. Now bring your finger close to it. What did you feel? What did you hear? If you were in a dark closet, what might you see? What is this spark?



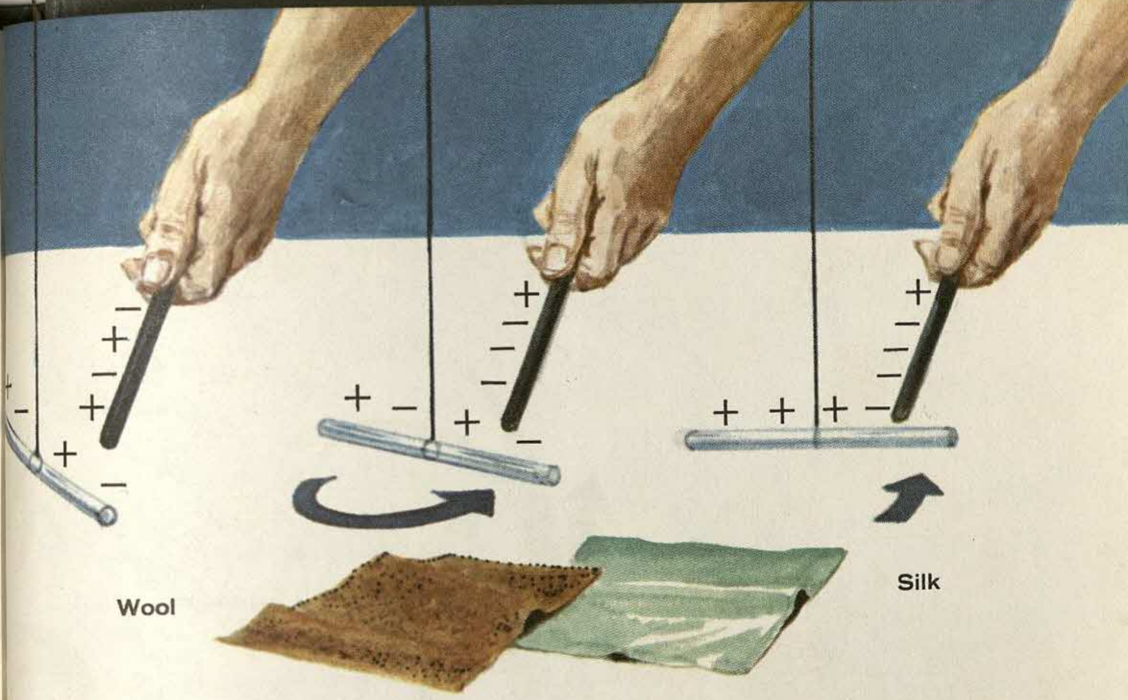
What charge was on the comb? By what method did you charge it? In what electrical condition was your finger when you pointed it at the comb? In which direction did the charge move? The shock, crackle, and spark are evidence of the movement of electrons.

Recharge your Leyden jar. Hold it in one hand, and touch the aluminum ball with the other hand. What happens? Why?

The Leyden jar stored static electricity, for the excess of electrons on the inside repelled electrons on the outside. These repelled electrons were absorbed by your body. The glass prevented the electrons from leaving the place of excess. From what you know about nature's tendency to restore a balance, what do you think lightning might be?

In 1752 Benjamin Franklin carried out his famous kite experiment. He attached a metal rod to a silk kite and held the kite by a silk thread. Near his hand he tied a key to the thread. Franklin flew his kite during a thunderstorm. When he put his hand near the key, a spark jumped to his fingers. Franklin showed that clouds and the earth, like a Leyden jar, store electricity. The lightning was the discharging. Franklin was very lucky to survive his experiment!

Why is lightning very severe at times and less severe at other times? When you rub a comb with wool, the charge build-up on the



comb is not great. Consequently, the discharge to your finger is a weak one. The charge build-up in the Leyden jar is greater. The discharge will be more powerful when the build-up of charge is greater.

Potential Difference

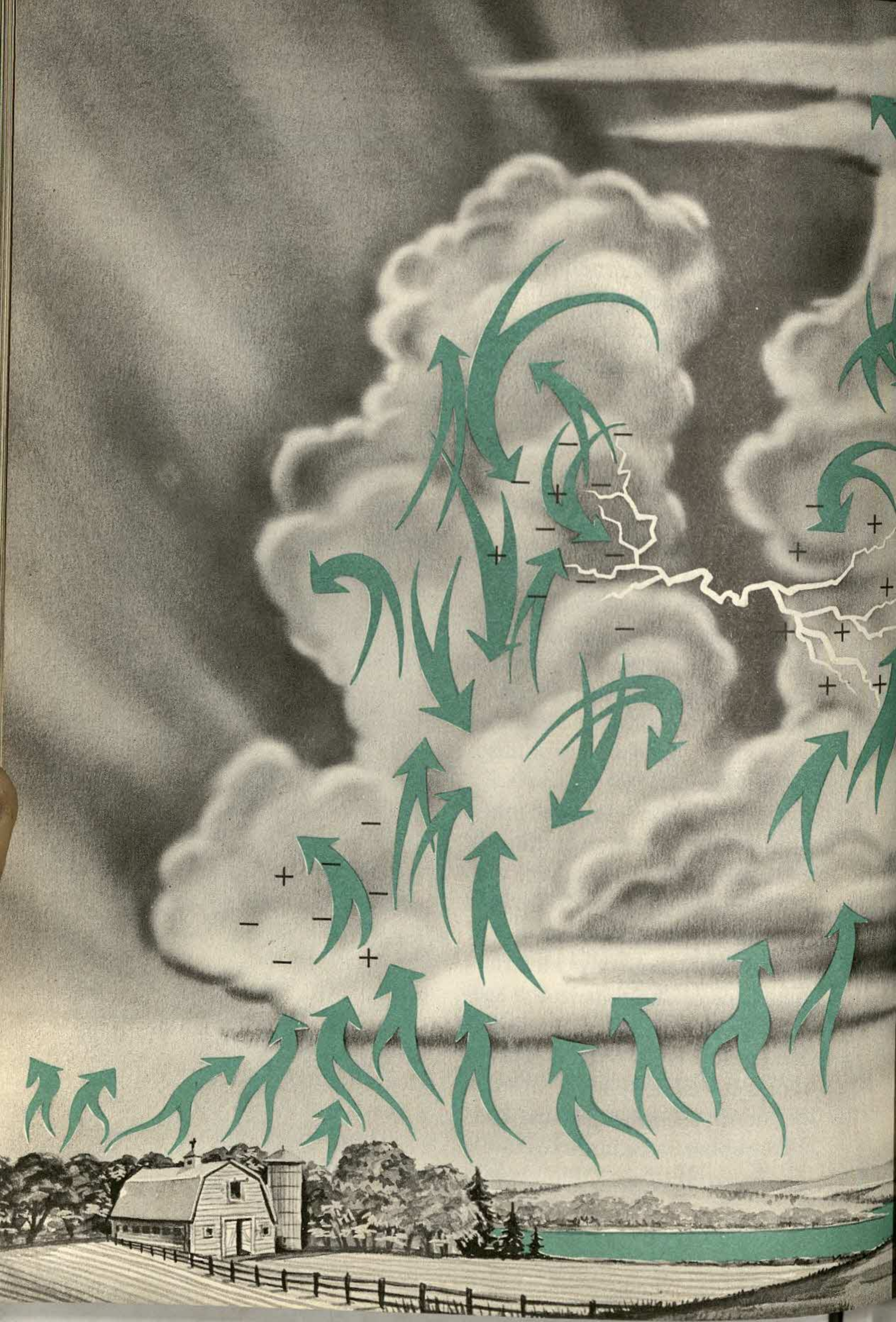
Examine the pictures. What is the electrical condition of the rods in the first picture? Is there any tendency to discharge? Explain your answer. What do the + and − signs tell about the electrical conditions of the rods in the second picture? Is their difference in charge very great? What kind of discharge takes place? Observe the rods in the third picture. How is the rubber rod charged? How is the glass rod charged? How would you compare their difference of charge with the difference of charge in the second picture? How will this affect the discharge? The difference in electrical condition between two objects is called the potential (po-TEN-sh'l) difference.

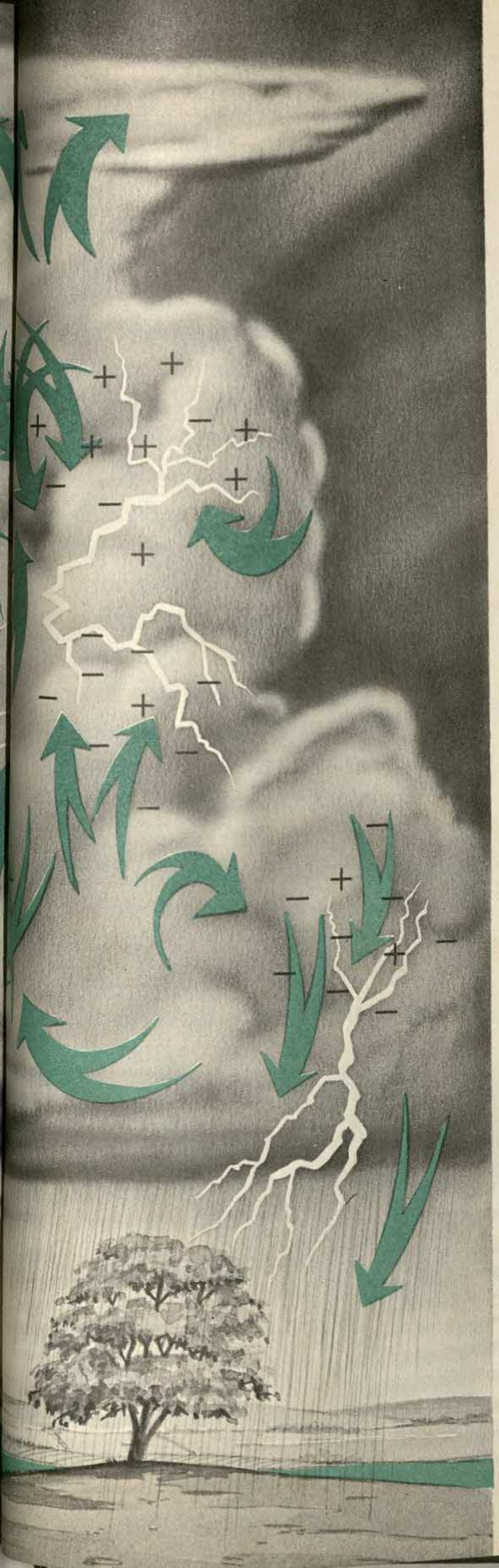
1. Two objects which are neutral or which are charged alike have no potential difference. There will be no discharge between them.

2. When there is a small potential difference between two objects, there will be a slight discharge.

3. When the potential difference is great, the discharge is great. If this discharge is rapid, a spark usually results.

Thunderstorms are associated with clouds that are anvil-shaped,





like the large one in the picture. These clouds may be as high as four miles and as long as seventy miles. They are called cumulonimbus (*kyoom*-yoo-loh-NIM-bus) clouds. Recent studies which were made by aircraft, radiosonde, and radar show that the air in these clouds is circulating violently.

What name is given to the circulating currents in fluids? What is necessary to start convection currents? In which direction does cold air travel? Why does warm air rise?

In the picture the strong updrafts of warm air are indicated by the arrows pointing upward. What do the arrows that point downward indicate? These conflicting currents produce violent circulations of air. Somehow, as a result of this turbulence, positive and negative charges are separated. After a great potential difference is built up, a bolt of lightning restores the balance. Lightning is thought to be a rapid discharge between electrified clouds—electricity in the sky.

Lightning can occur between unlike-charged portions of the same cloud. It can occur between two different clouds which have a difference of potential. It can take place between a cloud and the earth.

Electric Fields

TEST Hold both of the silk threads of your electroscope in your hands so that the puffed rice grains are very far apart. Have someone charge them for you. By transfer, charge one grain positively and the other one negatively. Now move the threads closer together very slowly. Watch for the first sign of an attraction between the puffed rice grains. How do you know that the attraction increases as the distance between the charged rice grains decreases? Repeat the process, starting at various distances. What do you observe?

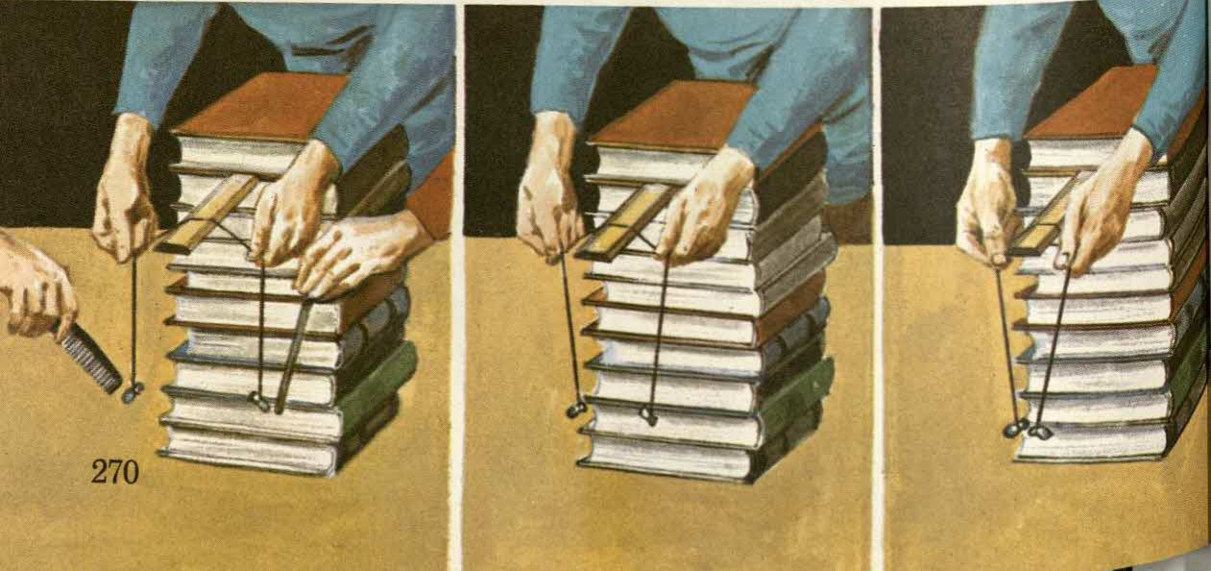
Is there a distance at which no attraction is evident? Are there distances at which the attraction is weak? When does the attractive force get stronger?

The attraction or repulsion between electric charges increases as the distance between them decreases. The closer two objects which have a potential difference come to each other, the stronger is the attraction between them. The closer two objects which have the same charge come to each other, the stronger is the repulsion between them.

The space around a charged object in which its force is felt is called its electric field. The greater the charge build-up, the greater will be the extent of the electric field. The field of a positively charged object is such as to attract electrons to the object.

Study the picture on page 268. What effect does a negatively charged cloud have on the barn? Why are electrons repelled from the tree down to the earth? Why do the barn and tree have a greater charge than the flat surface of the earth?

A charged cloud can affect the charge of an object which comes



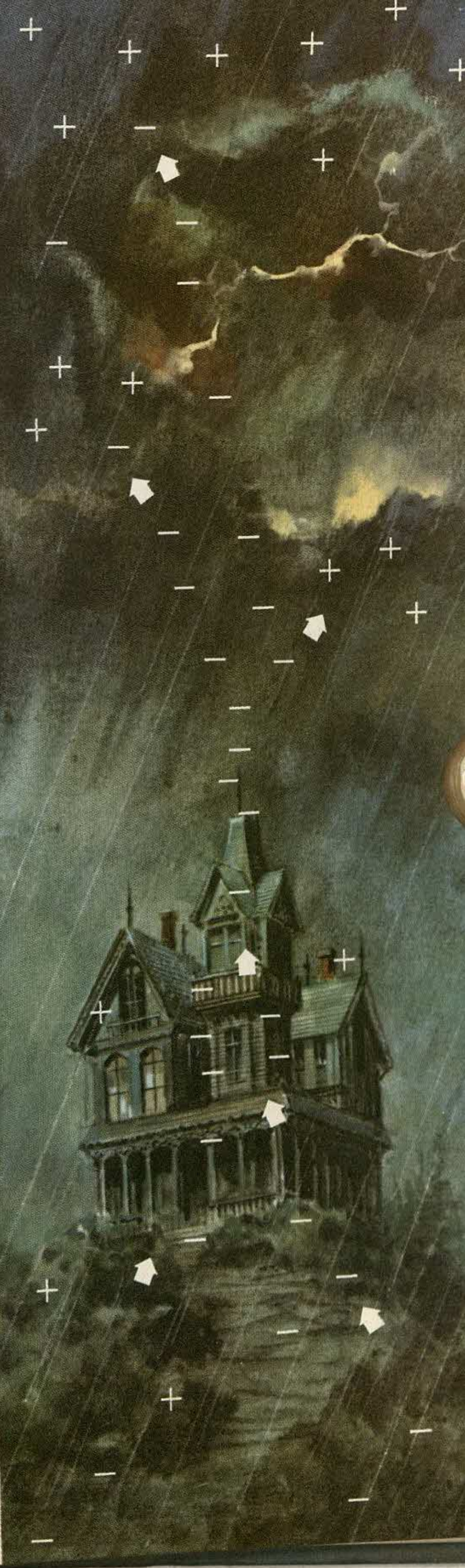
within its electric field. The closer to the cloud the object is, the greater will be this effect. If the part of the cloud nearest the object is positive, electrons will be attracted to the top of the object. If the part of the cloud nearest the object is negative, electrons will be repelled and the top of the object will be positive.

We have already spoken of charging an object by transfer—that is, by touching it to an object which is charged. Charging without contact is called charging by induction. When an object is charged by transfer, what charge will it have? When an object is charged by induction, what charge will the part nearest the charging object have?

Clouds that are charged induce the opposite charge on the earth's surface and objects upon the earth. If a sufficient difference of potential is built up, a lightning discharge will take place. The greater the difference of potential, the more severe will be the lightning stroke.

Lightning Rods

What are lightning rods? We can protect our homes and property by providing a pathway for the flow of electrons between clouds and the ground. Lightning



rods are metal rods that are connected to the ground by wires through which electrons can move. A material that permits the passage of electrons is called a conductor of electricity. A thick copper cable is a very good conductor of electrons. To be well grounded, it should end in underground water or moist earth. Charges collect on the outside of conductors and escape or flow into them most easily when the conductor is pointed. Therefore, lightning rods are thin and pointed.

Look at the picture on page 271. When a positively charged cloud hangs overhead, where are electrons most likely to build up? From where are they most likely to escape? As electrons leak from the tip of the lightning rod into the air, where will they be attracted? As electrons flow into the positively charged cloud, they neutralize its charge. Thus a lightning discharge is prevented and the house is protected. What do you think happens when a negatively charged cloud hangs over a house that is protected by well-grounded lightning rods?

Thunder

What causes the thunder that accompanies lightning? To answer this question, you must recall what you learned about heat. You must also know that the flash which you see is not the electrons in motion. You cannot see electricity, but only its effects. The flash involves tremendous numbers of molecules of air. These molecules have been made to glow by the energy they have acquired by collision with the electrons in the discharge. Some of the energy is transformed into the light of the flash. Some of it is transformed into heat. The air may be heated to a temperature of 54,000°F. What happens to air when it is heated? Imagine how quickly huge quantities of air are heated by a lightning flash! The explosive violence with which the air expands causes loud noises. These noises are echoed from the surfaces of the clouds. Thus the rumbling of thunder is caused. Will thunder harm you?

Will lightning strike the same place twice? The Empire State Building is struck on an average of thirty-eight times a year. Why is it not burned?

Safety Rules

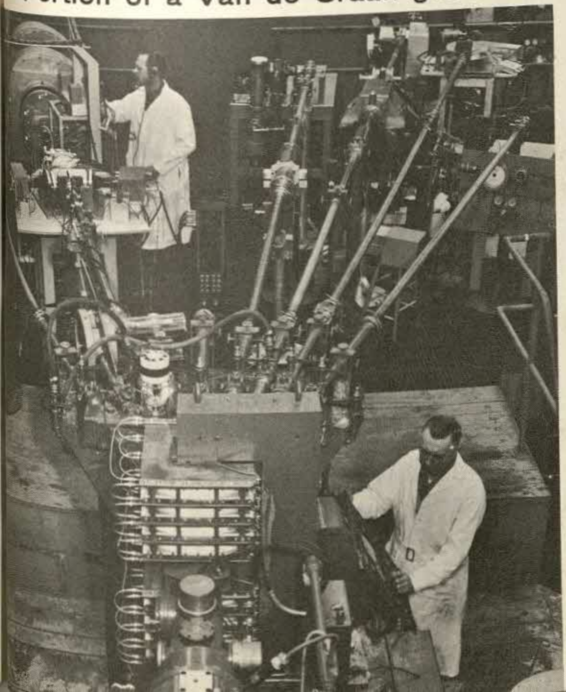
Here are some safety rules to follow in a lightning storm: 1. If you are caught outdoors, keep away from tall, isolated trees. 2. If you are in an automobile, stay there. 3. Keep off lakes and beaches. 4. Keep away from iron railings and wire fences. Discuss the reasons for each of these rules.

Static charges on objects on the earth may cause explosions and fires if they build up around inflammable materials. Why do gasoline tank trucks drag a chain along the ground?

Man-made Lightning

There are machines in which static charges are separated by friction and built up to high differences of potential. Examples of such machines are the Van de Graaff generator and the Wimshurst generator. These generators store static charges for use in devices called condensers or capacitors. The Leyden jar is a type of condenser. To be more useful, the electric discharge must be regulated so that it takes place without the uncontrolled violence of a spark. A flow of electric charges is an electric current.

Portion of a Van de Graaff generator.



Current Electricity

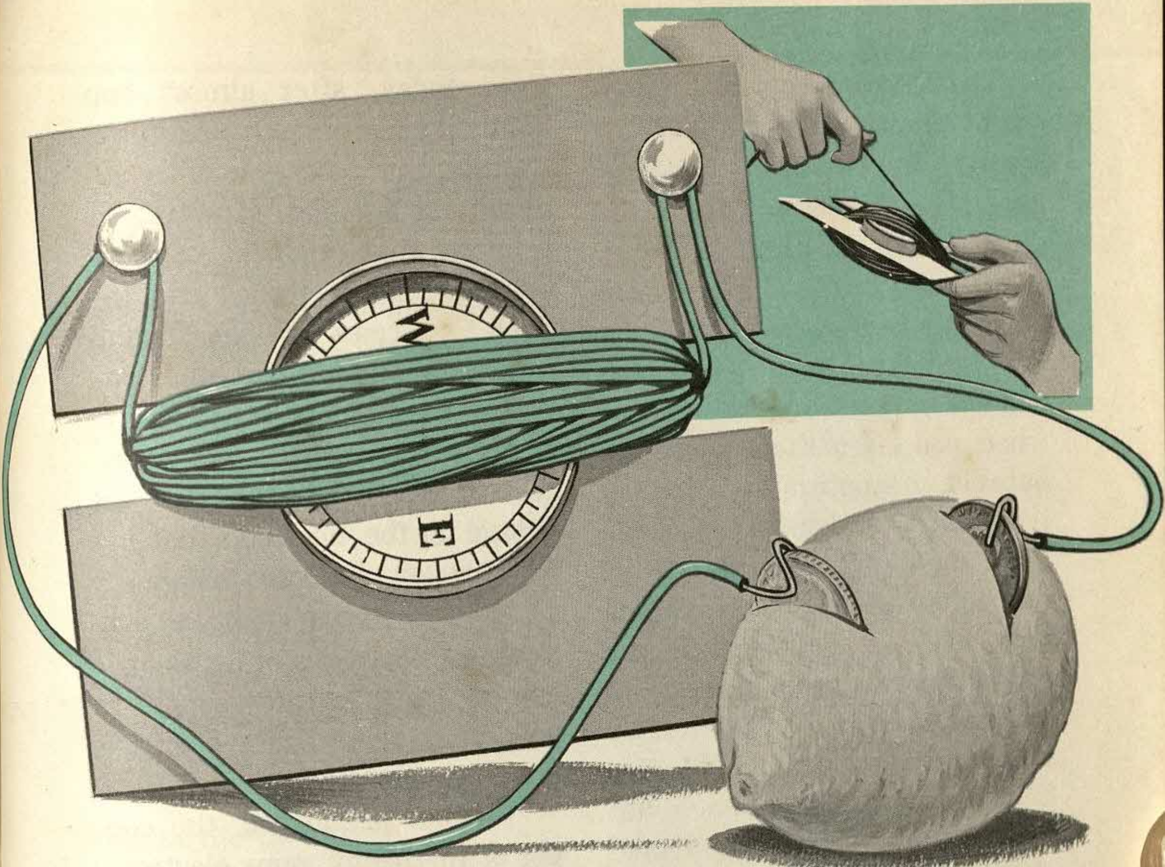
Controlling Electricity in Motion— Early Discoveries

About 1780, an Italian scientist named Luigi Galvani (1737-1798) was using a static electricity machine. The legs of a frog upon which he had been working twitched each time the machine discharged. Galvani attempted to explain this reaction. Whenever he touched the legs of the frog with a piece of brass and a piece of iron, the legs twitched. Galvani called the twitching "animal electricity" and thought there was something in the frog's legs that made the electricity.

Alessandro Volta (1745-1827) of Italy did not believe the electricity was "animal." Volta showed that immersing two different metals in certain liquids would cause an electric charge to flow through a wire connecting the metals. The two metals which become electrically charged are called electrodes (eh-LEK-trohdz). The liquid through which the electricity flows from one metal to another is called an electrolyte (eh-LEK-truh-lyte). This combination of two electrodes and an electrolyte is called an electric cell.

Detecting Current Electricity

ACTIVITY Before you learn any more about electric cells, you must prepare an instrument which will detect the tiny currents which you will get from your electric cell. You will need a compass, a square of cardboard which measures 5″ on each edge, 30 feet of bell wire, and 2 thumbtacks. Place the compass on the center of the cardboard, and cut a hole in the cardboard at both ends of the compass needle. Be sure the compass needle points directly at the holes. Wind the bell wire through the holes and over the compass and cardboard. You should have about 50 turns of wire. Leave about two feet of wire free at each hole. Stick thumbtacks at the edge of the cardboard, and catch the free ends of the wire around them once or twice. Bare about one inch of the free ends of the wire.



The instrument you have made will detect slight electric currents. This instrument is called a galvanoscope (gal-VAN-uh-skohp). After whom was it named?

Wet Cells

DESCRIBE You can make a simple electric cell somewhat like the one Volta first made. A simple electric cell can be made with a lemon, a penny, and a dime. Roll the lemon on a table to soften it a little. Then cut two slits in the lemon. Wash the coins with soap and water. Shine them with a clean cloth. Insert the penny in one slit and the dime in the other, as shown in the picture.

What metal in the penny serves as the electrode? What metal in the dime serves as the electrode? What electrolyte is used in this electric cell? Copper, silver, and the acid in the lemon juice make up your cell.

To test your electric cell, touch one of the wires of your galvanoscope to the penny. At the same time, touch the other wire to the dime. Watch the compass needle. What happens? The compass needle moves because there is an electric current in the wires. You will understand why this happens when you learn the relationship between magnetism and electricity. Test your lemon cell again. Note about how much the needle swings out of position. In which direction does it swing? If you can get a galvanometer, test your lemon cell with this instrument.

Test a lemon cell with two penny electrodes. Is there a current through the galvanoscope? Will there be a current through the galvanoscope if the lemon dries out? Explain your answers to the last two questions. ☐☐

Wet cells are sometimes called voltaic cells because Volta was the first to experiment with them. He tried many different combinations of metals and liquids, and found that each combination resulted in a particular amount of potential difference between the metal electrodes.

What did you learn about potential difference when you studied static charges? How do the electrodes become charged? Even today, after almost two hundred years of study and investigation, this process is not completely understood. However, it is known that chemical reactions between the electrodes and the electrolyte cause one electrode to gain electrons and the other one to lose them. What is the charge on the electrode that has an excess of electrons? What is the charge on the electrode that has a deficiency of electrons?

What happens when you connect the electrodes of an electric cell to your galvanoscope? In which direction will the electrons flow through the set?

In your lemon cell, the copper of the penny gains electrons. It has an excess of electrons. Is the penny the positive or negative electrode? The silver of the dime loses electrons. It has a deficiency of electrons. Is the dime the positive or negative electrode? To try to establish a balance of charge, electrons will move through the galvanoscope wire from the penny to the dime. The turning of the needle indicates this current. The electrons flow through the wire in one direction only. A flow of electrons in one direction only is called direct current. The abbreviation of direct current is D.C.

If electrons always flow from the penny to the dime through the wire, what would happen to the compass needle if you reversed the connections? Try it. Repeat this and observe what happens. What effect does reversing the connections have upon the turning of the compass needle? In what direction do the electrons always flow?

Dry Cells

COMPARE Is a dry cell really dry? Obtain an old dry cell, and ask an adult to cut it in half with a saw or a pair of heavy shears. Compare the dry cell with the one in the picture. □□

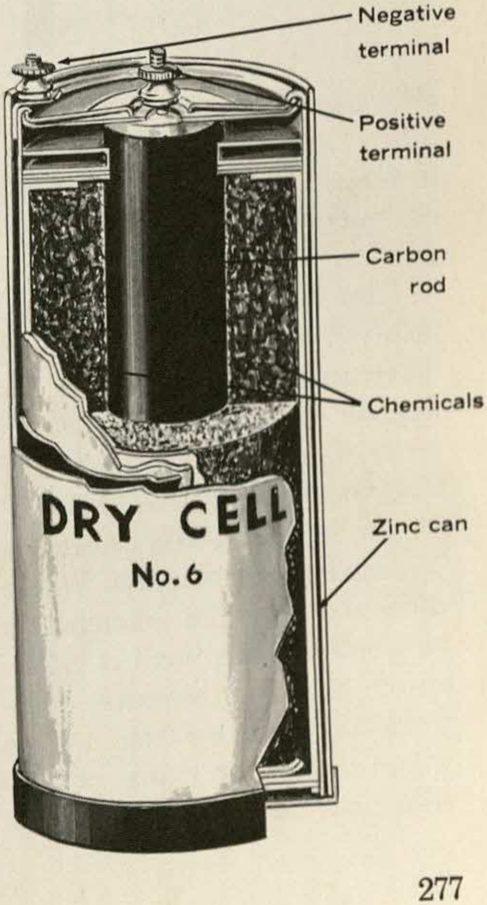
You can see that the dry cell is dry outside, but not inside. Inside is a wet paste consisting of a mixture of chemicals. Locate the binding posts to which you connect the wires. The outside post is attached to the can, which is made of zinc. The zinc of the can is the negative electrode. To what electrode is the inside binding post connected? The rod in the center of the cell is carbon and is the positive electrode. Name the essential parts of the dry cell.

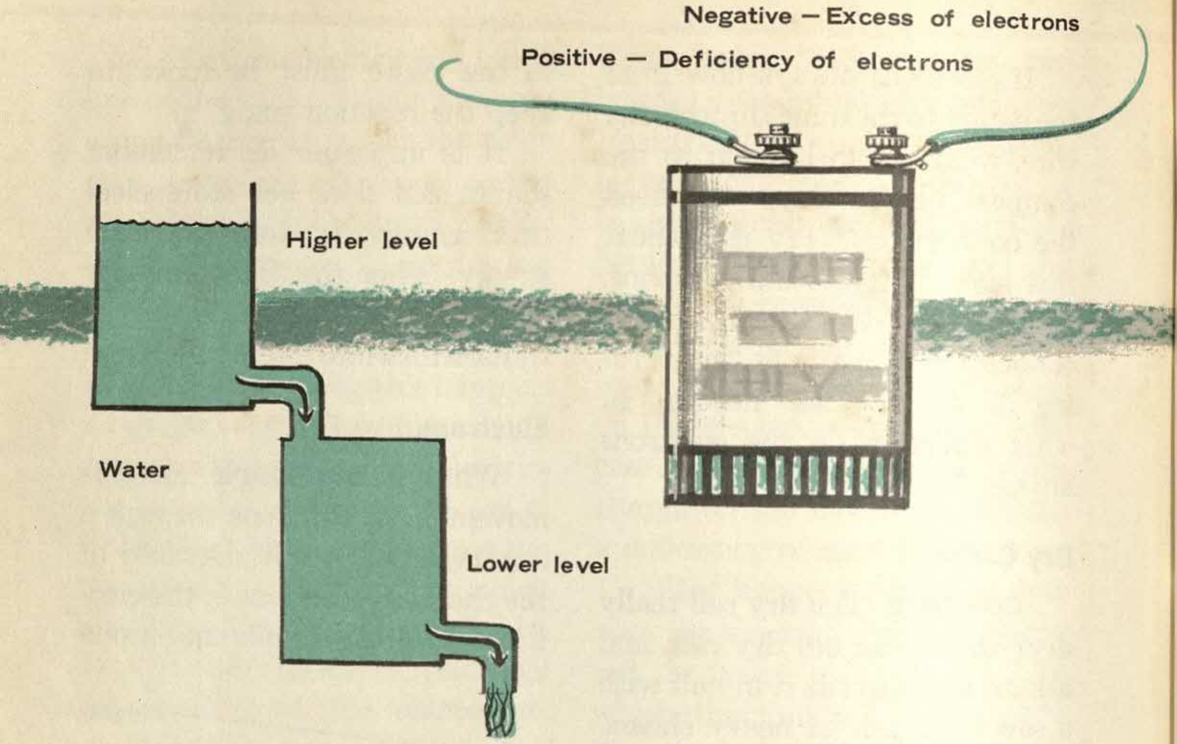
When a dry cell will no longer supply current, it is said to be "dead." The electrodes must be free to react with the electrolyte, so the paste must be moist to keep the reaction going.

It is important to remember that a cell does not store electrical energy. It stores chemical energy. When the cell is properly connected, its chemical energy is transformed into electrical energy.

Electromotive Force

What is responsible for this movement of electrons through a conductor by a cell? Because of the chemical reactions in the electric cell, electrons pile up on one




Negative — Excess of electrons
Positive — Deficiency of electrons
Higher level
Water
Lower level

electrode. They are lost by the other electrode. This difference in the electrical condition of the electrodes is called potential difference.

The following example may help you to understand potential difference. Where there is a difference between two levels of water, water flows from the higher level to the lower level. The difference in water levels causes unbalanced water pressure. Where there is a potential difference in an electrical cell, there is unbalanced electrical pressure. Electrons tend to move from a place where there is an excess of electrons to a place where there is a deficiency of electrons. The tendency of the cell to produce the excess and deficiency of charge at its electrodes is called the electromotive force of the cell. It is abbreviated e.m.f. The potential difference and the e.m.f. are *related*, but they are *not the same*. The potential difference refers to the difference in the electrical pressure between the electrodes, but the e.m.f. refers to the tendency of the cell to develop this potential difference.

The e.m.f. and the potential difference of an electric cell are both measured in units called volts. From where did this name come? A cell having zinc and copper electrodes has an e.m.f. of 1 1⁄10 volts (1.1v). The silver and copper cell has a lower e.m.f., while the zinc and carbon cell has an e.m.f. of 1½ volts (1.5v). What is marked on your dry cell?

The standard dry cell used in the U. S. has zinc and carbon electrodes. Examine as many different size dry cells as you can find. Why are they all marked 1.5v? Larger cells simply have more materials, so they will produce larger currents.

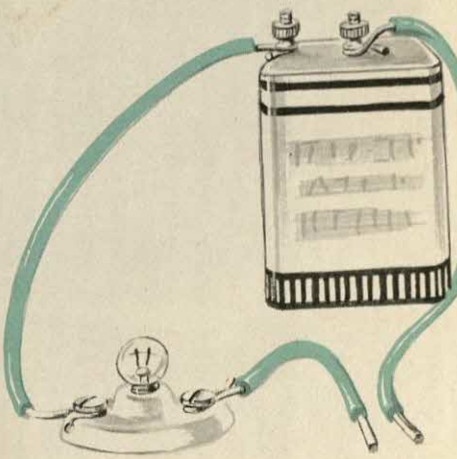
A Simple Circuit

To be useful for work, energy must be controlled by man. Can the electrical energy of lightning be used by man to run his machines? Man must make the electrical energy go where he wants it to go. The controlled pathway for an electric current is called a circuit.

A simple circuit is shown in the picture. How many parts does it have? A dry cell is the source of energy. The electric light bulb is the user of electrical energy. The connecting wires complete the pathway for the flow of electrons. Why is the circuit in the picture not complete? A broken or incomplete circuit is called an open circuit. Electrons will not flow through an open circuit.

DISCOVER You can build a circuit. You will need a 1½ (1.5) volt dry cell, a 1.5 volt flashlight bulb and a socket to fit it, three ten-inch lengths of bell wire, a screwdriver, and a knife.

Using the knife, bare all the ends of the three pieces of bell wire. What kind of wire is underneath the covering? Why is the wire covered? Connect the ends to the dry cell and to the lamp socket as shown in the picture. To test your circuit, put together the two free bared ends of wire. When these are in contact, what kind of circuit do you have? What should happen when the circuit is closed? If the bulb does not light, check all connections. Are they tight? Is the bulb screwed all the way down? Are the dry cell and bulb in good working condition?



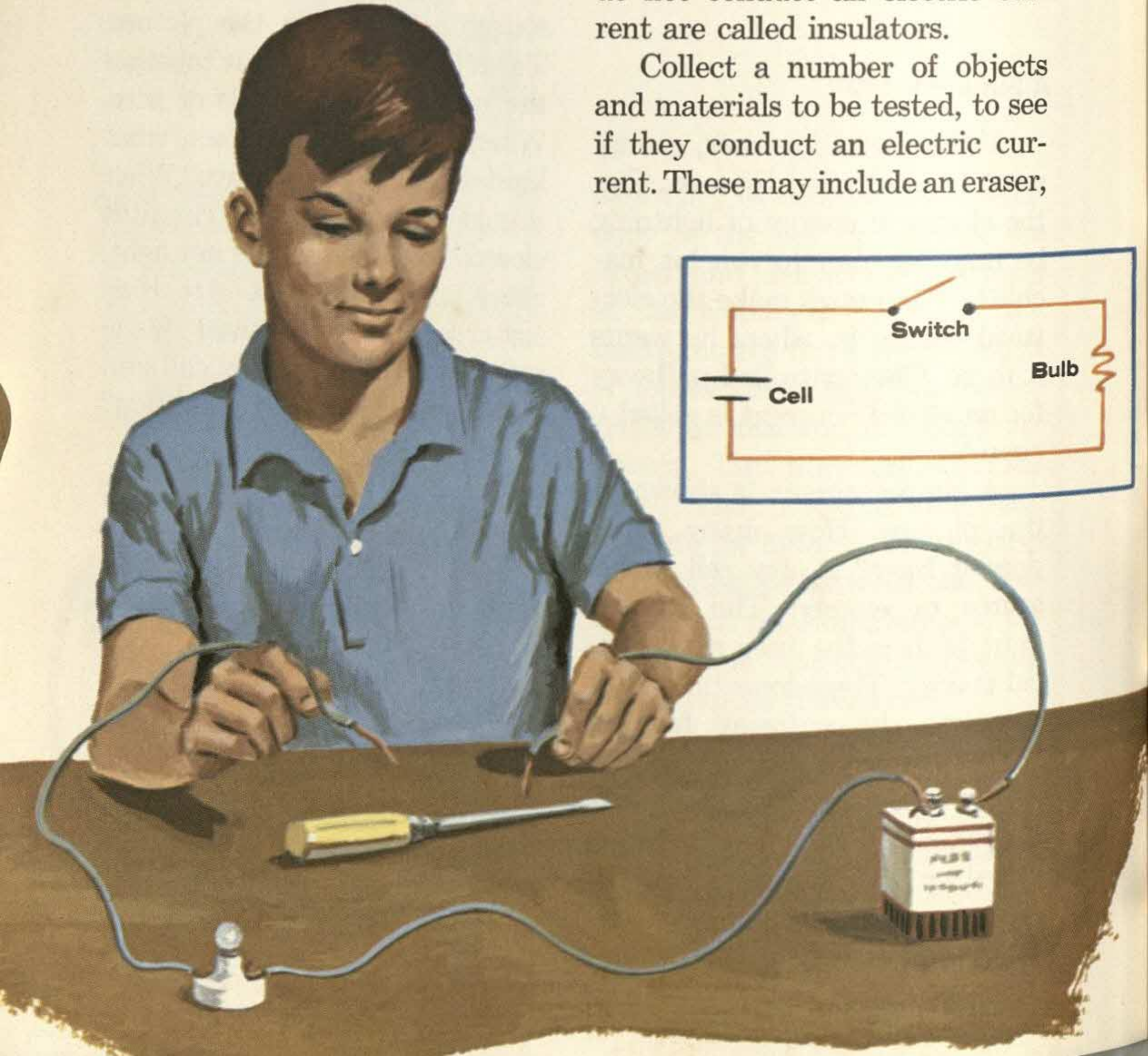
Conductors and Insulators

DESCRIBE Touch the bared ends of the free wires to the blade of the screwdriver. Does the blade permit the current? How do you know? Now test the handle of the screwdriver. Does it conduct an electric current? Why is the handle of an electrician's screwdriver made of a material which does not conduct an electric current?

When you draw a diagram of an electric circuit, you may use symbols to represent the parts of the circuit. The symbol ⎓ represents one cell, ⋀⋀⋀ represents the bulb, and _/ _ represents a break in the circuit.

What name is given to materials that conduct heat? What name is given to materials that do not conduct heat? Materials that permit an electric current are called conductors. Those that do not conduct an electric current are called insulators.

Collect a number of objects and materials to be tested, to see if they conduct an electric current. These may include an eraser,



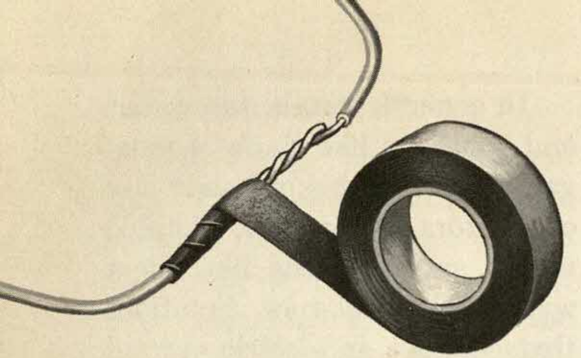
tin can, rubber ball, aluminum pan, glass dish, silver fork or spoon, any kind of painted or unpainted metal object, a paper clip, paper, a plastic toothbrush container, a comb, chalk, wood, silk, wool, a piece of carbon (coal or the center of an old dry cell), distilled water, tap water, a vinegar and water solution, salt water solution, sugar water, and baking soda solution.

Test the materials which you have gathered by inserting them into the circuit one at a time. Record your observations, identifying the materials as conductors or insulators. When you have finished you should be able to reach a general conclusion about metals and certain solutions compared with nonmetals and other solutions.

In general, metals, tap water, and solutions like those of vinegar, salt, and baking soda are conductors. Nonmetals, distilled water, and solutions like sugar water are insulators. Solutions that conduct an electric current are called electrolytes. Nonconducting solutions are called nonelectrolytes.

What is the purpose of the conductors in a circuit? What parts of your circuit are conductors? Why are some materials in a circuit insulated? How does the circuit help you to control the electric current? □□

By using a circuit, man can control the flow of electrons. The conductors make the electric current go where man wants it, and the insulators prevent it from going where he does not want it.

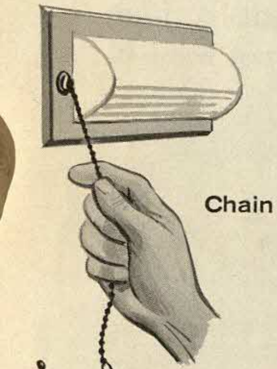


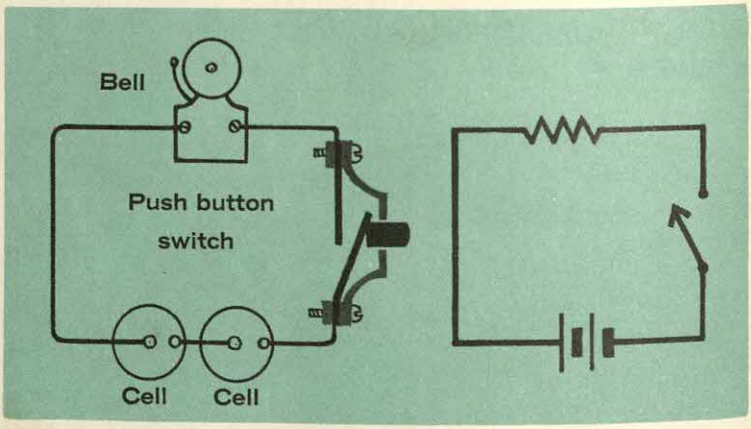
Insulators prevent you from receiving electric shocks. They prevent loss of electrical energy. The dry cell is the source of energy in your circuit. It, too, has conductors and insulators in it. The metal connecting wires, the wire in the bulb, and the metal parts of the socket are conductors. The rubber or plastic coating on the connecting wires, the glass of the bulb, and the base of the socket are insulators.

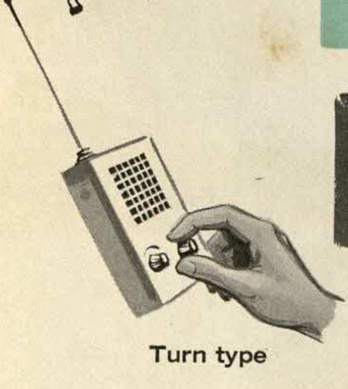
Splicing Wires

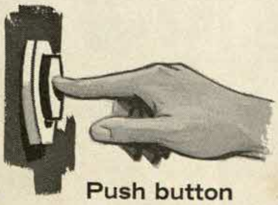
To join wires in a connection, bare about 2 or 3 inches at the end of each wire. Twist the ends of the wires together tightly. Then cover the bared parts completely with electrician's tape, as shown in the picture. Be sure to overlap the tape and the wire's own insulation. What is the purpose of the electrician's tape? Will just any kind of tape do? Explain your answer.

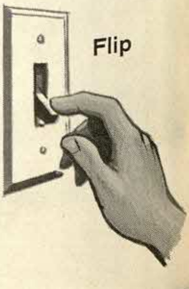
How does a circuit help you to use an electric current? What must you do to a circuit to produce a current through it? Are the electric circuits in your home closed all the time? How do you know?







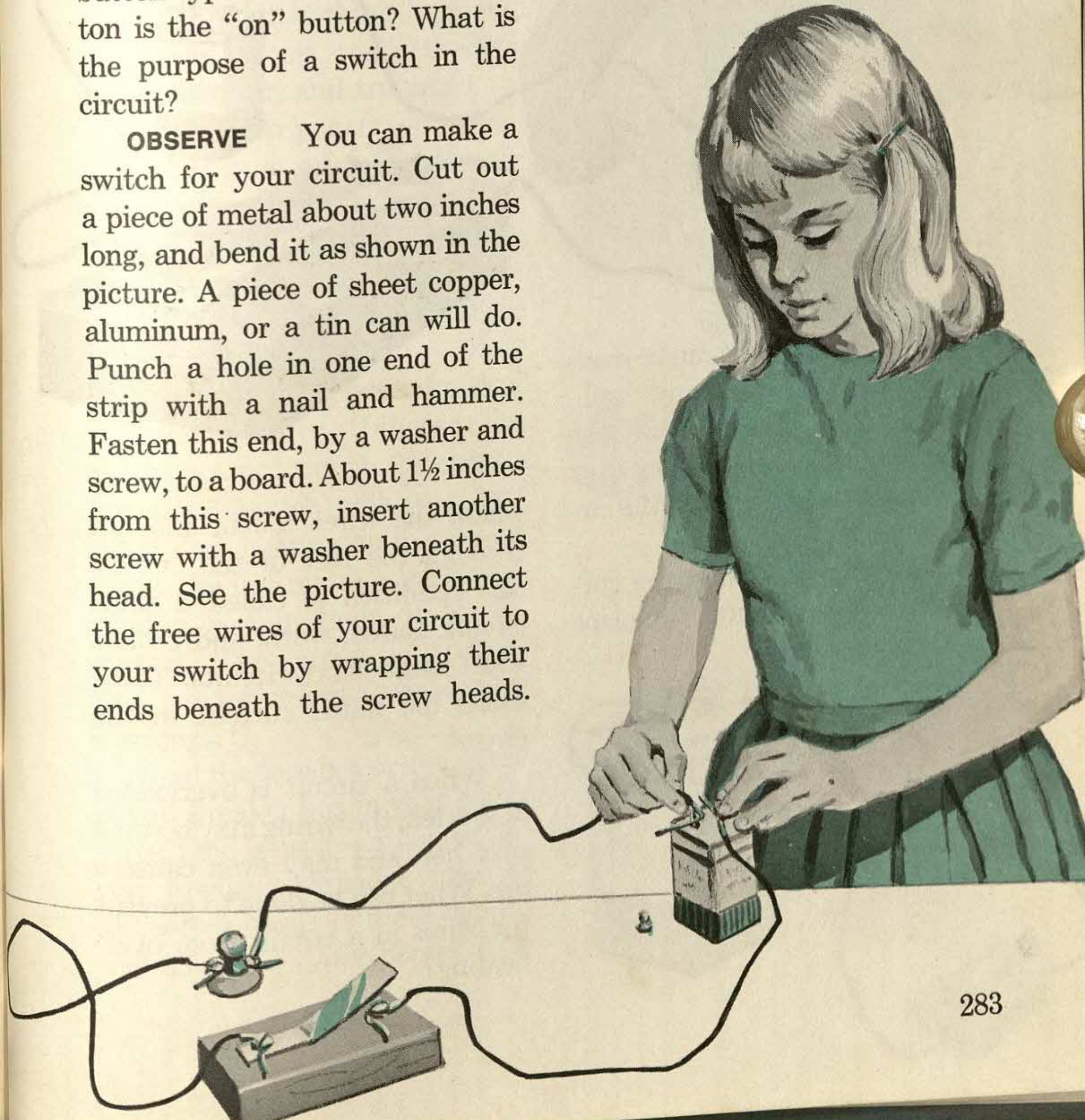




Switches

How do you control the light circuit in your classroom when you need light? Where is the switch in your classroom? When the circuit is closed and all of its parts are working properly, the light should be lit. What is marked on the switch when the circuit is closed? If it is a double push-button type of switch, which button is the "on" button? What is the purpose of a switch in the circuit?

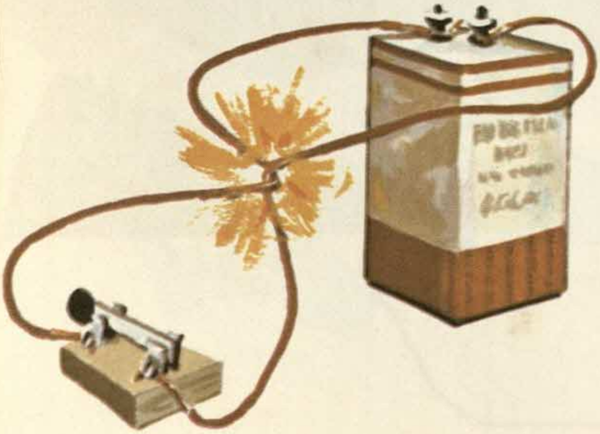
OBSERVE You can make a switch for your circuit. Cut out a piece of metal about two inches long, and bend it as shown in the picture. A piece of sheet copper, aluminum, or a tin can will do. Punch a hole in one end of the strip with a nail and hammer. Fasten this end, by a washer and screw, to a board. About 1½ inches from this screw, insert another screw with a washer beneath its head. See the picture. Connect the free wires of your circuit to your switch by wrapping their ends beneath the screw heads. Test your switch by pressing the free end of the metal strip against the screw head beneath it. Trace your circuit. Is it a complete one? What is your proof? Open your circuit. You are making (closing) and breaking (opening) your circuit with a switch. You can now control not only the path of the current, but also the time during which there is current.



Fuses

An electric circuit can be overloaded; that is, too many appliances can be plugged in at the same time. The appliances may require more current than the circuit is designed to give.

If bared wires touch, the current will occur through the place where the wires touch, and not through the rest of the circuit; this condition is called a short circuit. Bared, worn, and broken wires cause short circuits. These cause too much current in the circuit.



When a circuit is overloaded or shorted, the wiring may become very hot, and may even cause a fire. What can be done to prevent the wires in a circuit from overheating?

DISCOVER Take a block of soft wood, two thumbtacks, and a very narrow strip of aluminum foil. Tack the foil to the block of wood. Remove the light bulb and its socket from the circuit you have been using. Attach the ends of the connecting wires to the thumbtacks. Close your circuit with the switch. What happens to the foil? If nothing happens, break the circuit, make the foil strip narrower, and try again.

The foil strip acts as a fuse. The fuse is a safety device. It melts when there is too much current in the circuit. Examine a new fuse and a burned-out fuse. What happens to the circuit when the fuse melts? ☐☐

An automatic circuit breaker is a kind of switch. If there is too much current through the circuit, the metal switch gets very hot. What does heating do to metals? When the hot metal expands beyond a certain limit, it breaks contact. The circuit is opened. You are warned that something is wrong.

Find the fuse box or automatic circuit breaker box in your home. What kind is used—automatic circuit breaker, cartridge fuse, or screw-base fuse? Is there one for each circuit in your home? How

many circuits are there in your home? Where do you insert appliances in the circuits? How many receptacles or outlets are there in your living room? Are they all on the same circuit?

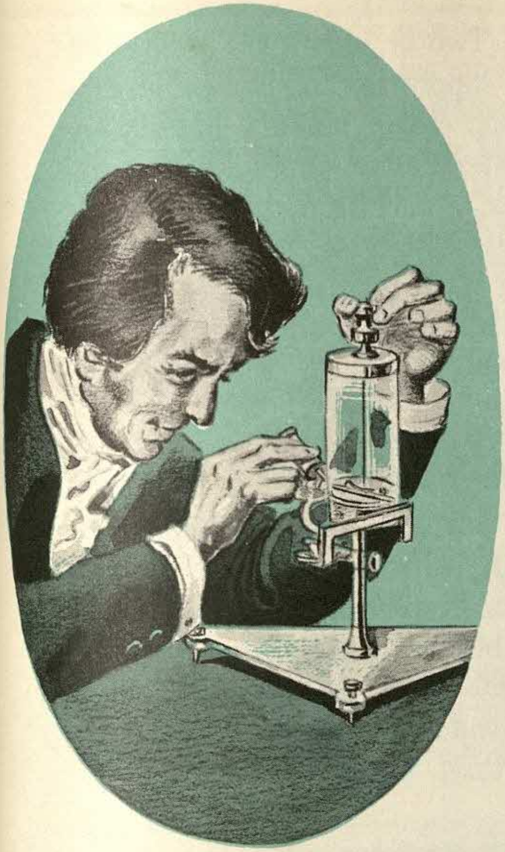
Safety Rules

1. Electric wires or cords that have a worn covering should never be used in an electric circuit.
2. Electric wires, cords, switches, fuses, or appliances that are connected in a circuit should not be touched with wet hands.
3. Switches should be repaired immediately if you get a shock when you use them.
4. New fuses should replace "burned out" ones. Never insert a penny behind an old fuse to close the circuit.
5. Replace a blown-out fuse with a fuse of the proper number.

Ohm's Law

Your dry cell lighted the small electric light bulb because its potential difference was strong enough to force sufficient current through the bulb. The tendency of a material to oppose the flow of electrons is called electrical resistance. The amount of current a cell is capable of supplying depends upon its e.m.f. and its electrical resistance. Why doesn't the lemon cell light the bulb? The e.m.f. of a cell depends upon the materials and the electrical condition of the cell.

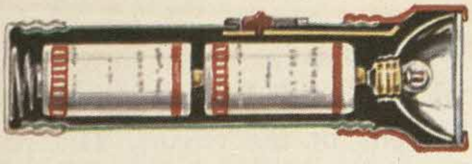
Examine a regular light bulb What is the voltage marked on it? Find the marking on your small bulb. Why do they differ? It takes a greater electromotive force to push the necessary current through the regular bulb. Notice the fine wire inside the light bulb. Electric current through this wire heats the wire and causes it to give off heat and light. The wire is called a filament. The filament of the more powerful bulb offers more resistance to the electrons. Imagine yourself trying to get through a crowd of people who are pushing



and shoving in all directions. After you make your way through the crowd, how will you feel? Will you have used much energy to get through the crowd? The electrons meet resistance from the atoms of the wire filament.

Georg Simon Ohm (1787-1851), a German school teacher, was the first to recognize an exact relationship between the e.m.f., resistance of conductors, and the amount of current. Ohm made a study of the resistance of conductors to the flow of electrons through them. He found that when he increased the resistance, he decreased the strength of the current in the circuit. The relationship between e.m.f., the amount of current, and the resistance is called Ohm's law. Ohm's law is very important to electricians.

Remember—the greater the e.m.f., the greater is the current. The greater the electrical resistance, the less is the current. The e.m.f. is measured in units called volts. After whom is this unit named? The current is measured in units called amperes. André Ampère (1775-1836) was a French scientist who studied electric currents.



We can write Ohm's law as follows: current equals the e.m.f. ÷ resistance.

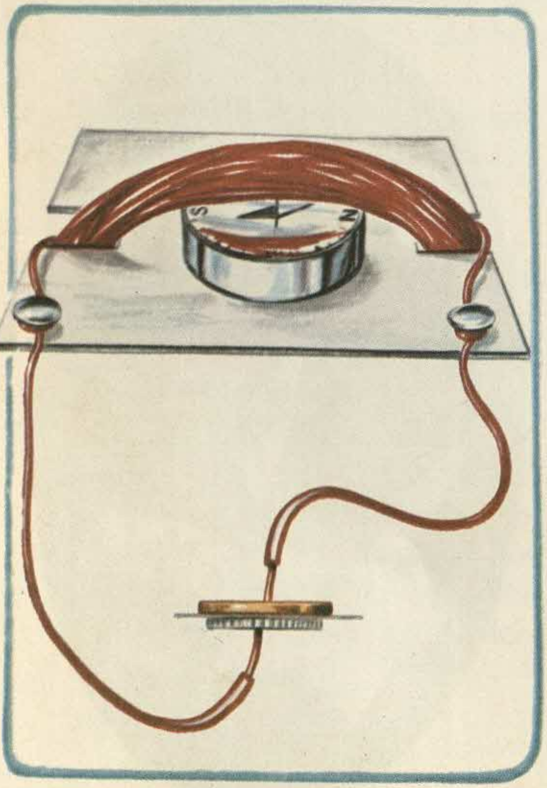
Batteries

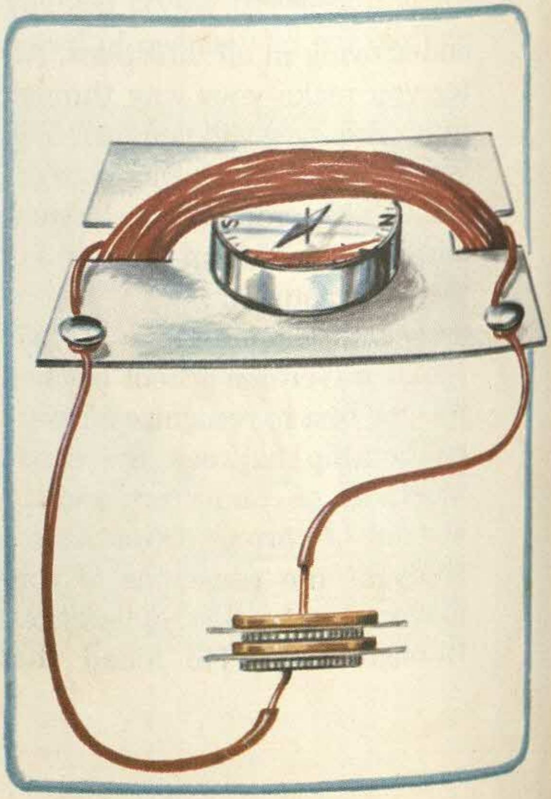
Examine a flashlight. How many dry cells are there in your flashlight? Trace the circuit in your flashlight. How many volts does your flashlight require? Examine a transistor radio. How many cells are there in the transistor radio? Some transistor radios require 6v; others require 9v.

Two or more cells connected to supply electric current in the same circuit make a battery. A battery may supply a greater e.m.f., or it may supply more materials to last longer, depending upon the arrangement of its cells. You will study about these arrangements in the following activities.

Cells in Series

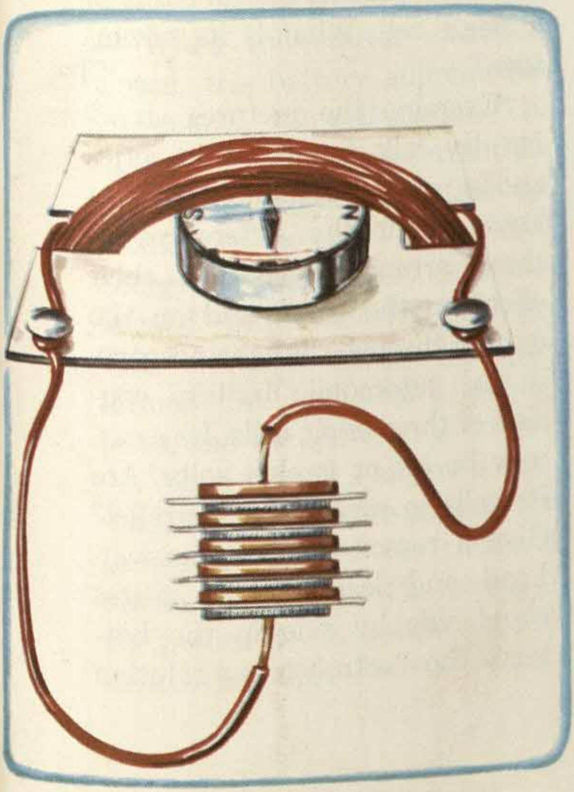
ACTIVITY Shine five pennies and five dimes as you did for your lemon cell. Moisten a piece of blotting paper (paper towel, facial tissue, desk blotter) with saltwater solution. Place the wet blotting paper on one of the





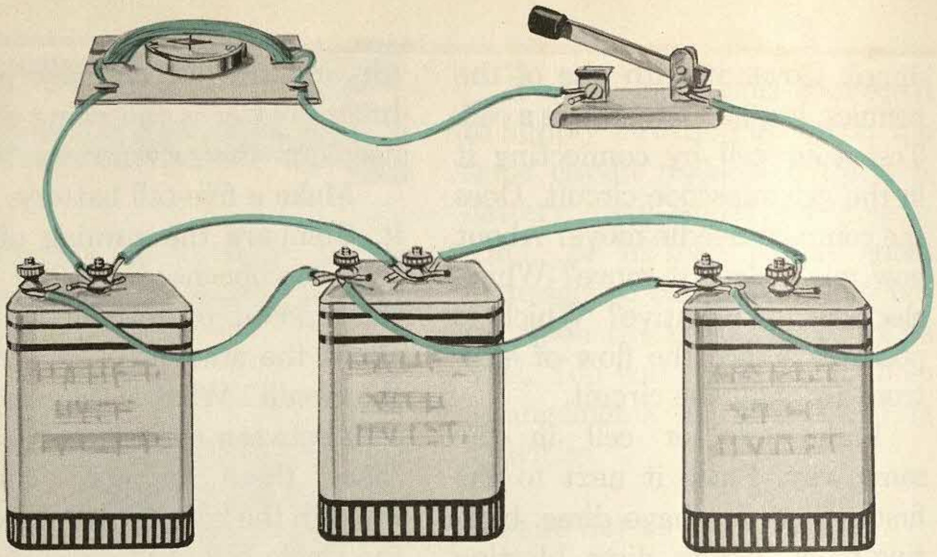
dimes. Cover it with one of the pennies. Explain why this is a cell. Test your cell by connecting it in the galvanoscope circuit. Does the compass needle move? About how much does it move? Which electrode is negative? Which is positive? Trace the flow of electrons through the circuit.

Make another cell in the same way. Place it next to the first cell so you have dime, blotting paper, penny, dime, blotting paper, penny. What does the two-cell arrangement give you? Test your battery by inserting it in the galvanoscope circuit. Does the compass needle turn more or less than it did before? What does this indicate? About how many times greater is the swing of the needle in the galvanoscope?



Make a five-cell battery. Test it. Compare the turning of the galvanoscope needle. What does the amount of turning indicate about the amount of current in the circuit? What is the relationship between current and e.m.f.? Since there is more current through the battery than through the single cell–and since the resistance of the circuit is about the same–is the e.m.f. of the battery greater or less than that of the single cell? Placing cells in series is like placing water tanks one above the other. The difference in water level is increased, so the e.m.f. of a series circuit is increased.

Cells connected so that the negative electrode of one cell is in contact with the positive electrode of the next are said to be arranged in series. Check your arrangement of cells. Do you have a series battery? The e.m.f. of a series battery is the sum of the e.m.f. of all the cells in the battery. How must the cells of a flashlight battery be arranged so that the flashlight works? Why are there diagrams in the back of some transistor radios showing how the cells are to be put in?



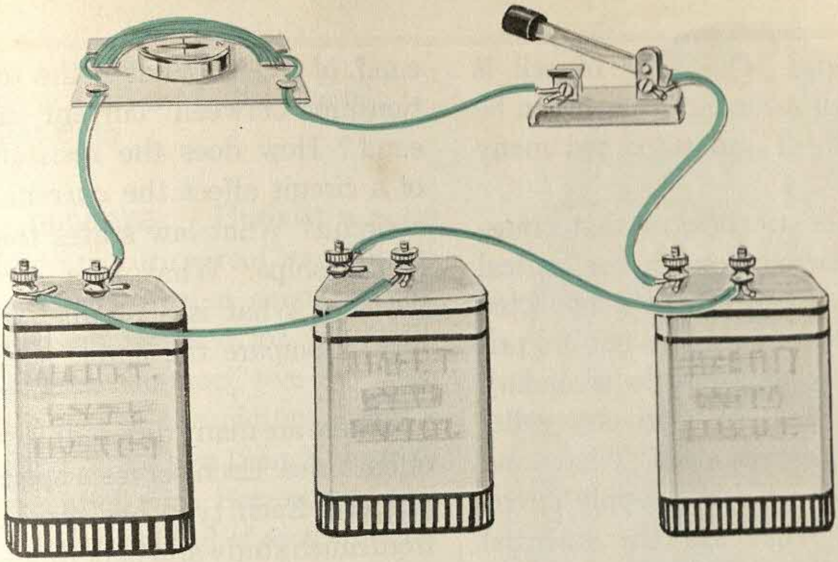
Cells in Parallel

ACTIVITY Connect two dry cells by joining the positive electrode of one cell to the positive electrode of the other, and the negative electrode of one cell to the negative electrode of the other. Test this battery with your galvanoscope. Add one more dry cell to your battery, and test with your galvanoscope again. Since the needle turns the same amount for two or three cells in this arrangement, what can you conclude about the current from such a battery? Does the e.m.f. increase as cells are added to the battery? Placing electric cells in parallel is like connecting water tanks on the same level. The water will last longer, but there is no more water pressure.

A connection of positive electrode to positive and negative to negative is called a parallel arrangement. A battery consisting of cells in parallel has an e.m.f. of a single cell. What is its advantage? □□

Examine the pictures showing dry cells connected in series and in parallel. Explain what you know about the differences in these arrangements and their effect on the e.m.f. and on the current through the galvanoscope.

An automobile battery consists of three or six cells. Its e.m.f. may be six or twelve volts. Are its cells in series or in parallel? Give a reason for your answer. Lead and lead dioxide plates stand side by side in the battery. The electrolyte is a solution



of acid and water. Complicated chemical reactions, which charge one electrode negatively and the other electrode positively, take place.

When the starter switch is closed, the battery supplies the current for the self-starter. The battery also supplies current for the lights, heater, and other appliances in the car. The chemical energy of the battery is transformed into electrical energy. This electrical energy is transformed into heat, light, and so forth, and the battery discharges.

When the car's engine is running, the electric current from the generator reverses the chemical action of the cell. The recharging process is the reverse of the discharging process. Electrical energy is transformed into chemical energy. Sometimes it is necessary to use an electric current from an outside D.C. source to recharge the battery.

Why should you not use the car radio for long periods of time when the car is not running?

Primary and Secondary Cells

Cells such as the voltaic and dry cells are called primary cells. Their materials can be used until they are used up. Then they must be replaced. The chemical action of the cells cannot be reversed.

The chemical energy of a storage battery can be restored by reversing the chemical action of its cells. This is done by an electric current from an outside source. New materials need not be added. This type of cell is called a secondary cell. It can be discharged and recharged many times.

Cells are devices that transform chemical energy to electrical energy when they are connected in a closed circuit. What are primary cells? How do secondary cells differ from primary cells? What do cells store? What kind of current do cells supply in circuits? What are the essential parts of any cell? What is the e.m.f. of a cell? What is the relationship between current and e.m.f.? How does the resistance of a circuit affect the current in a circuit? What law states these relationships? What is a series battery? What is a parallel battery? Compare the e.m.f. of the two.

There are many different types of batteries. Each serves a special purpose. Each type has resulted from much study and experimenting on the part of many men. Even though chemical reactions in batteries are not completely understood, man benefits from these reactions in many different ways.

Use of Current in the Electric Light Bulb

OBSERVE Untwist a piece of iron picture wire. Cut off about three inches of a single strand. This will be used for your bulb filament. Connect two dry cells as shown in the picture. Insert a switch. Take two 12-inch pieces of copper bell wire. Bare about three inches at one end of each wire. Insert these ends through two holes in a cork stopper. You can make these holes with a thin nail. Use melted candle wax to fasten the wires in the cork stopper. Connect the single strand of iron wire to both of the copper wires. Wind the excess iron wire around the copper wires. Fasten the cork stopper securely in the mouth of a glass jar. Complete the circuit. What happens?

What is the source of energy? Close the switch until the filament begins to glow. Open the switch. You may be able to light your lamp several times. □□

Thomas Edison (1847-1931) invented the first electric lamp which was useful for practical purposes. Edison used a burned cotton thread for his filament. Your filament was iron, which, when heated, united with the

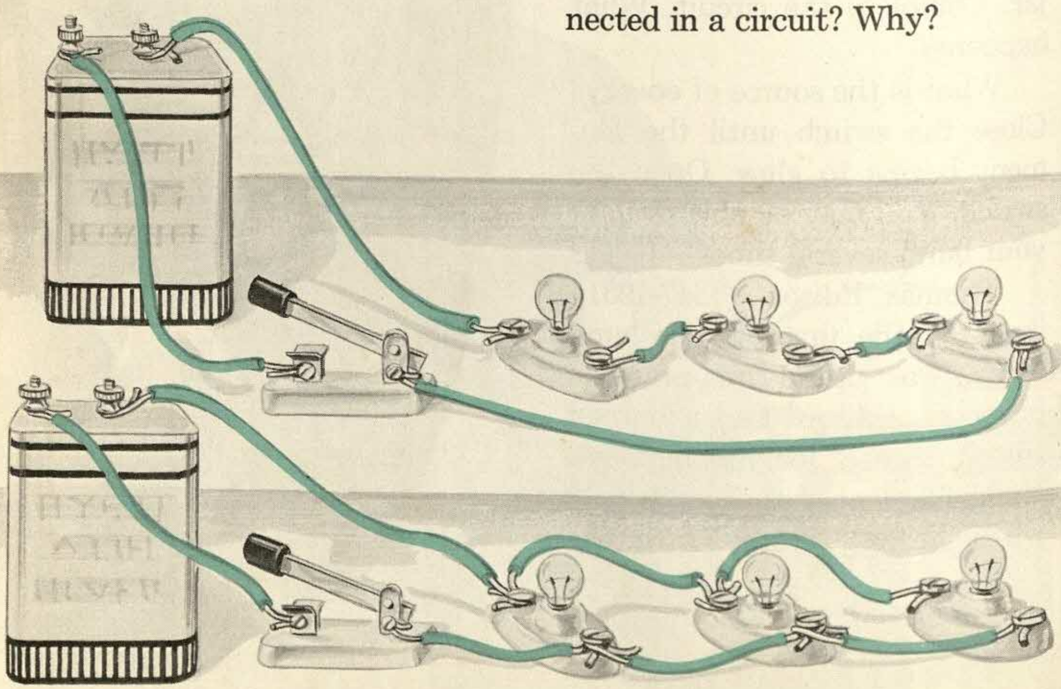
oxygen of the air inside the jar. Today, regular light bulbs do not have oxygen in them. Their filaments are made of tungsten (TUNG-st'n). This metal can be heated, without melting, to a higher temperature than the melting temperature of iron; hence, tungsten gives a brighter light. Is tungsten a good or poor conductor of electricity? Does it offer little or much resistance to the electric current? Into what forms of energy was electrical energy transformed in the light bulb? Which of these do you want from the bulb? Which represents a loss of energy?

DESCRIBE Complete a circuit for a small electric light. Use one dry cell. Arrange a series circuit for two electric lights. What do you notice about the brightness of each light? Did you increase or decrease the resistance in the circuit? How did this change in resistance affect the current? the e.m.f.?

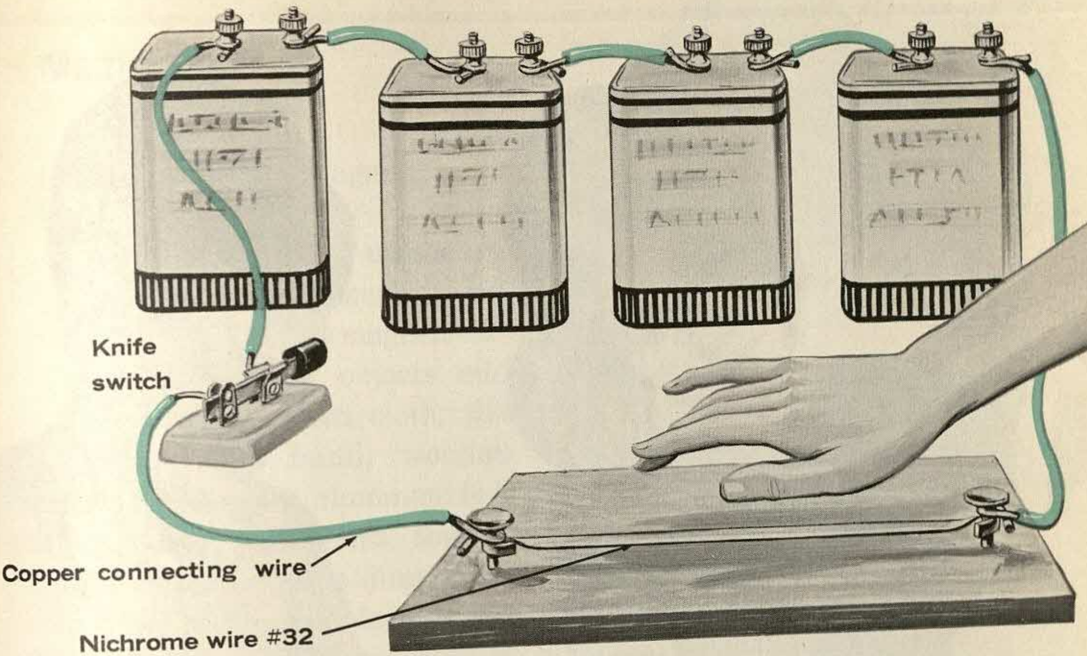
Arrange a series circuit for three light bulbs. What do you notice? How could you increase the brightness? Unscrew one bulb. What happens? Why?

Draw a circuit of the three bulbs in series. The symbol should be used for light resistance. How should a switch always be connected in a circuit? Why?

Try the lights in a parallel circuit. Study the picture of three light bulbs in a parallel circuit. What happens if you unscrew one light? Why are appliances in a house arranged in a parallel circuit? How should fuses be connected in a circuit? Why?



SIMPLE HEATING ELEMENT



Use of Current in the Electric Toaster

ACTIVITY Examine an electric toaster. How does the electrical energy get into the toaster? Plug the toaster into an outlet and turn it on. How do you know that electrical energy is going into the toaster? What kinds of energy can you identify as you look into the toaster? Which kind is most important to the purpose of the toaster? Which kind is less important to the purpose of the toaster? A poor conducting wire is used in a toaster in order to cause heat in the wire. In both the electric light bulb and the toaster, electrical energy is transformed into light and heat energy. Both have electric wire conductors which get hot and glow.

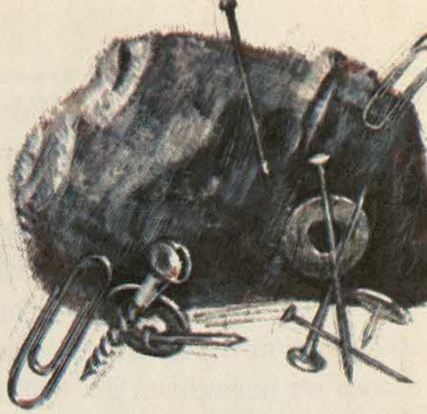
The wires in a toaster are much longer than those in a light bulb, and are made of a special mixture of metals called Nichrome (NY-krohm). The Nichrome wire is flat, and radiates heat more readily than the thin wire in a light bulb. So a toaster is designed to convert most of the electrical energy which enters it into heat energy. Explain why the cord on a toaster does not get hot, even though it carries the same amount of current as the heating filament. What other electrical appliances have for their purpose the transformation of electrical energy to heat energy?

PUFFED RICE
LUMINUM FOIL

Magnetism

Magnetic and Nonmagnetic Materials

ACTIVITY What are the objects which the boy and girl are examining? What do magnets do? Cut the following objects into small pieces: woolen cloth, silk cloth, rubber band, wooden matchstick, paper, aluminum foil. Collect some iron nails, thumbtacks, copper wire, a dime, plastic toothbrush container, a tin can, puffed rice. Touch each of these with your magnet. Which materials are attracted to the magnet? What do nails, thumbtacks, and the tin can contain which might explain their being attracted to the magnet? The nails are made of iron. Thumbnails are made of iron. Thumbtacks are usually steel, which has a high percentage of iron. Why are brass thumbtacks not attracted to the magnet? The tin can is made of iron, coated with tin. Besides iron and steel, cobalt (KOH-bawlt), nickel, and some mixtures of metals are attracted by a magnet. One of these mixtures is alnico (AL-ni-ko). It contains aluminum, nickel, cobalt, and iron. Which of these metals will be attracted when tested with a magnet? Which of them will not be attracted to a magnet when tested alone?



Materials which are attracted to a magnet are called magnetic (mag-NET-ik). Those which are not attracted to a magnet are called nonmagnetic.

Natural Magnet

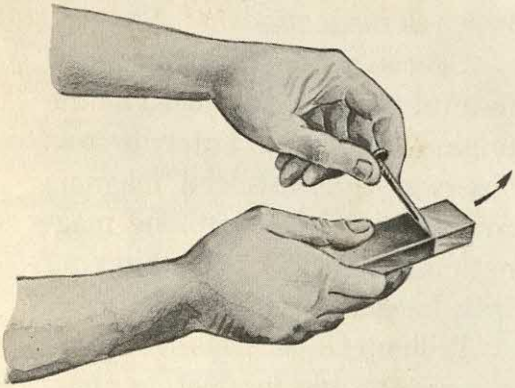
Over two thousand years ago, a certain kind of stone was found to be magnetic. The name lodestone was given to it. Lodestone means "leading stone." Today we know that this kind of stone contains a certain kind of iron ore which is magnetic.

Special pieces of lodestone, a natural magnet, were used as the original compass. Later it was observed that artificial magnets could be made by stroking magnetic materials in a certain way with lodestone.

William Gilbert was even more famous for his interest in magnetism than for his interest in static charges. He was the first to call the ends of a magnet "poles." Gilbert suggested that the earth itself acted like a magnet. This is why one end of a magnet seeks the north and the other end seeks the south. Gilbert published a book on magnetism in 1600. In this book he explained how he had studied the behavior of magnets. You can do these experiments, too.

Artificial Magnets

OBSERVE If you have a strong bar magnet, you can magnetize a nail, a sewing needle, or a hacksaw blade. Stroke the iron nail firmly with one end of a magnet fifteen times. Stroke in one direction only. Cut some steel wool into very fine pieces, or file an iron nail to get some iron filings. Test your nail magnet at both ends by poking it into the filings. Does it attract the filings?



Make a magnet from a sewing needle or a hacksaw blade. These are steel, and may take longer to magnetize. After several days, test the iron magnet and the steel magnet again. Did either of them lose some of its magnetism? Soft iron is easily magnetized, but it loses its magnetism easily. How long does steel hold its magnetism? Materials which lose their magnetism easily are called temporary (TEM-peh-*rair*-ee) magnets. Those which keep their magnetism for a long time are called permanent magnets. However, even permanent artificial magnets lose their magnetism in time, especially if they are dropped or heated.

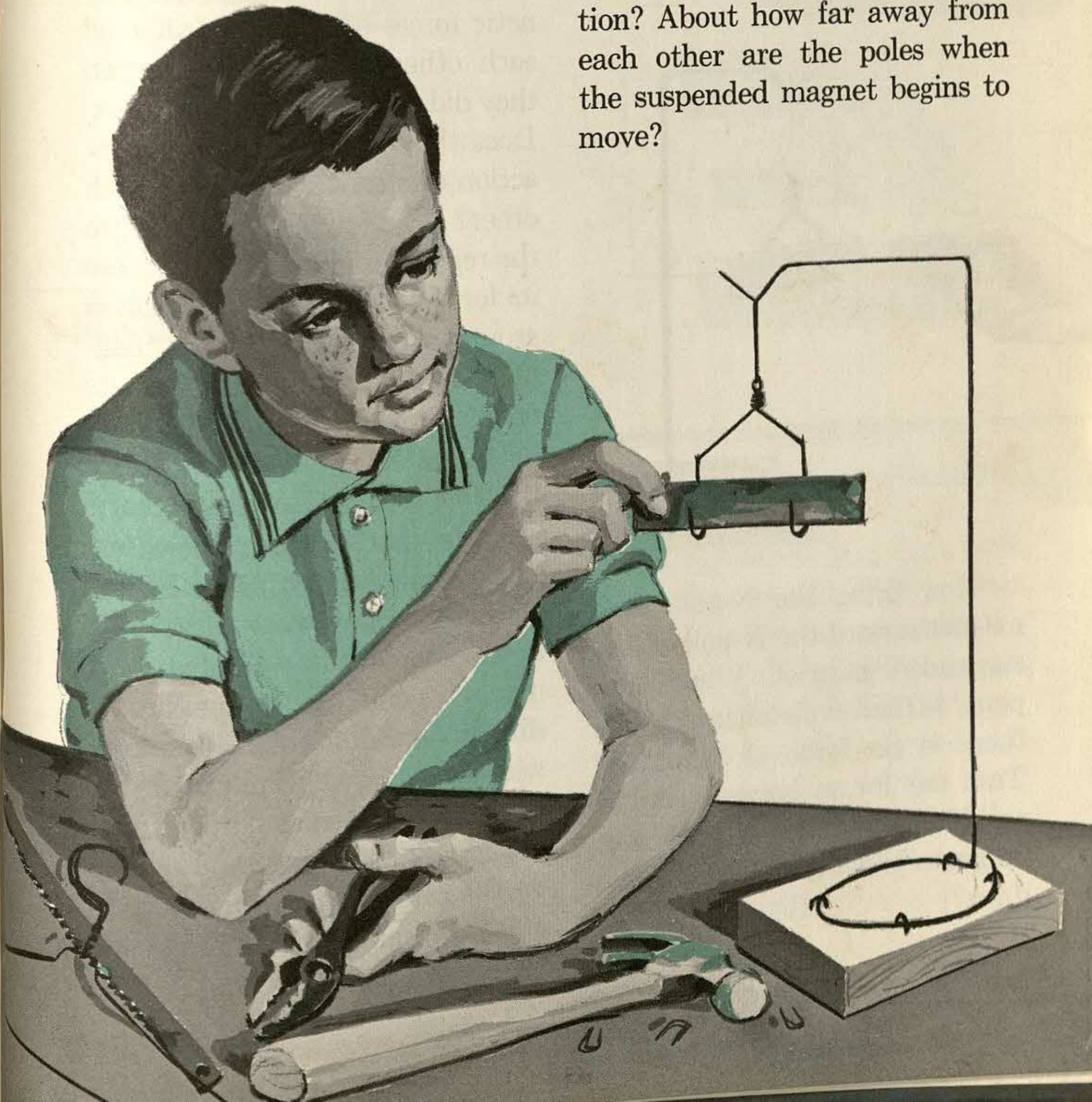
Magnetic Poles

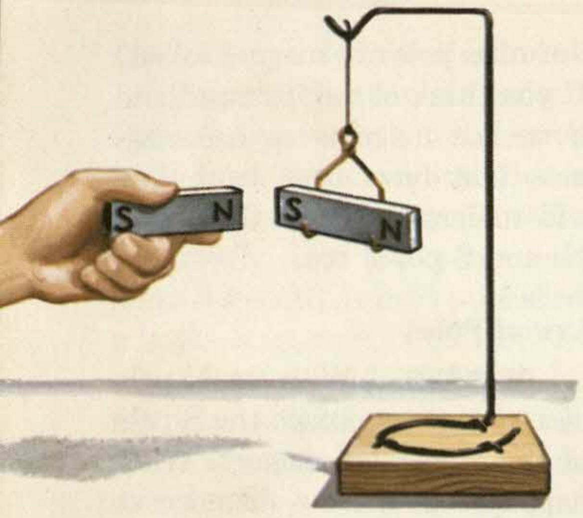
EXPLORE Where does the magnetism seem to be concentrated in a magnet? Spread some steel tacks or pins on the table. Place your magnet on top of them. Lift the magnet gently. Where do most of the tacks cling? The regions of a magnet where its magnetism is concentrated are called its poles. Many magnets have a pole marked "N." Why is this so marked?

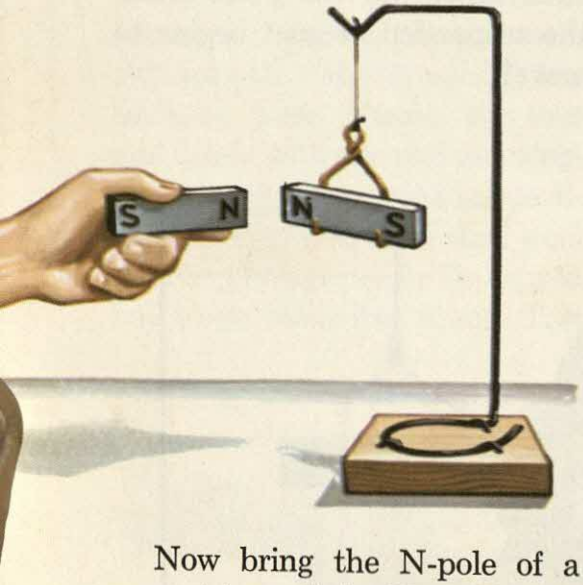
DISCOVER Make a frame of copper wire such as the one you see in the picture. Tie a string to the frame and place the magnet in the frame. Suspend the magnet so it is balanced. When the magnet comes to rest, in which direction is its N-pole pointing? Why is the N-pole called the north seeking pole? Suspend your nail and needle magnets. Locate and mark their N-poles. What is the other pole of a magnet called? If you think of the U-shaped and horseshoe magnets as bar magnets that have been bent, you will understand that they have N- and S-poles, too.

Law of Poles

OBSERVE With the N-pole of a magnet, approach the S-pole of the suspended magnet. What happens? Is there a distance at which there is no force of attraction? About how far away from each other are the poles when the suspended magnet begins to move?







Now bring the N-pole of a magnet toward the N-pole of the suspended magnet. What happens? Is there a distance at which there is no force of repulsion? Test the forces between unlike and like poles of several different magnets. What conclusion do you draw? ☐☐

The Law of Magnetic Poles states that unlike poles attract each other; like poles repel each other.

Magnetic Fields

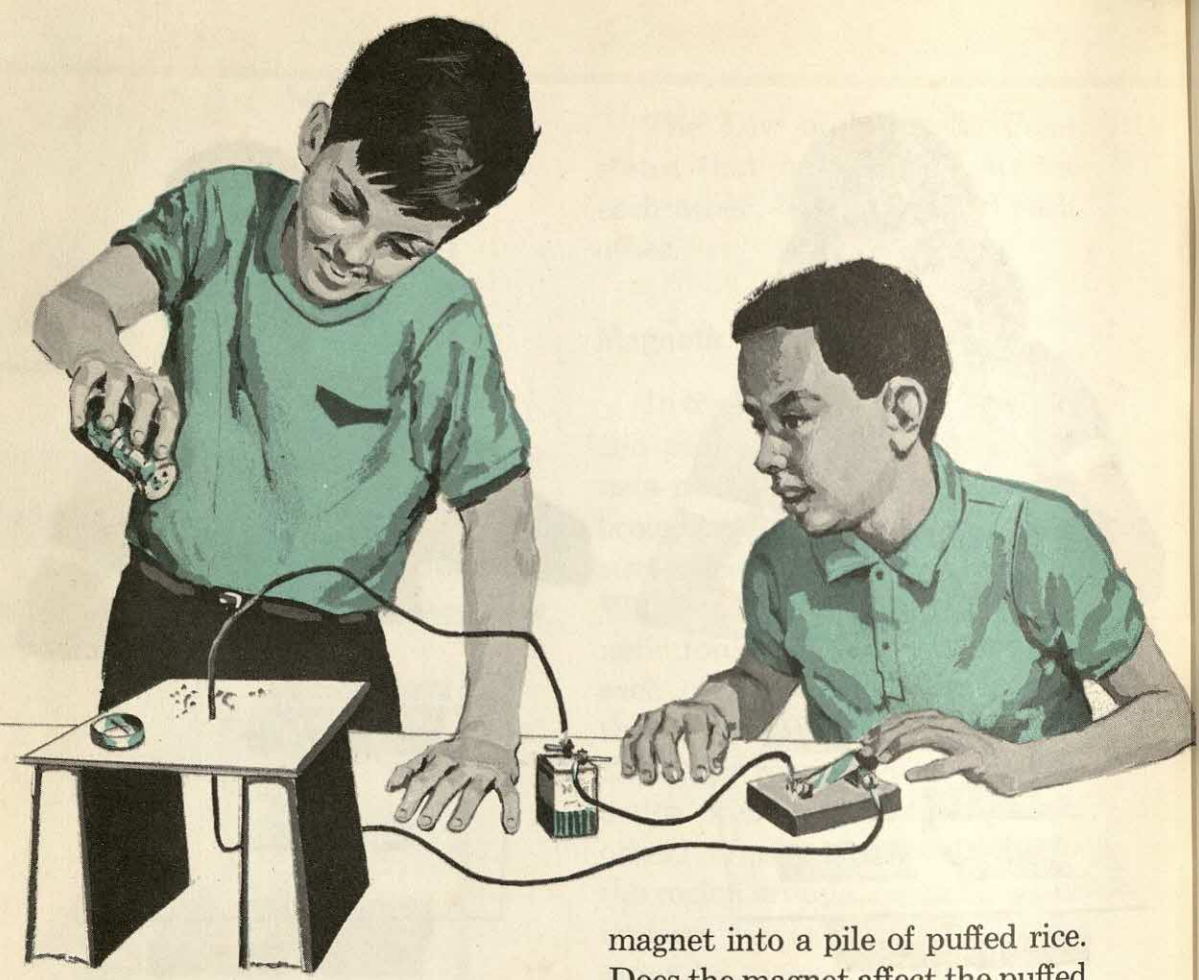
In the last activity you brought the poles of two different magnets near to each other. As you brought them closer, you saw the suspended magnet begin to move. Within a certain region the magnetic forces of the poles affected each other. Outside that region they did not influence each other. Does this remind you of the reaction of electric charges to each other? What name was given to the region around a charge where its force was exerted? The region around a magnet where its magnetic force is acting is called its magnetic field.

COMPARE You can study the shape and size of magnetic fields in the following activities. Place a piece of white cardboard or a piece of window glass over a bar magnet. It should extend much beyond the magnet in all directions. Fill an old salt shaker with iron filings. From about one foot above the magnet, sprinkle the iron filings lightly and evenly on the cardboard or glass. Tap it gently to help the iron filings line

up in the field. Do the iron filings form a pattern? Where are most of them concentrated? A force moves the filings into a definite pattern. Where does this force come from?

Now place the N-pole of one magnet and the S-pole of another magnet about an inch apart, as shown in the picture. Cover and sprinkle with iron filings, as you did before. What does the pattern tell you about the interaction of the fields around unlike poles?

Repeat what you have just done, using two like poles. What does the pattern tell you about the interaction of the fields around like poles? Investigate the magnetic field around U-shaped and horseshoe magnets in this same way. How are the magnetic fields around all the magnets similar? How do they differ?



Magnetism and Electricity

What is the Law of Electric Charges? What is the Law of Magnetic Poles? What is an electric field? What is a magnetic field? Do these likenesses mean that electricity and magnetism are the same force? Charge your comb by rubbing it with a woolen cloth. Will the charged comb attract iron filings? Stick your magnet into a pile of puffed rice. Does the magnet affect the puffed rice? Are electrical and magnetic forces identical? What other tests can you use? What do you conclude? Why?

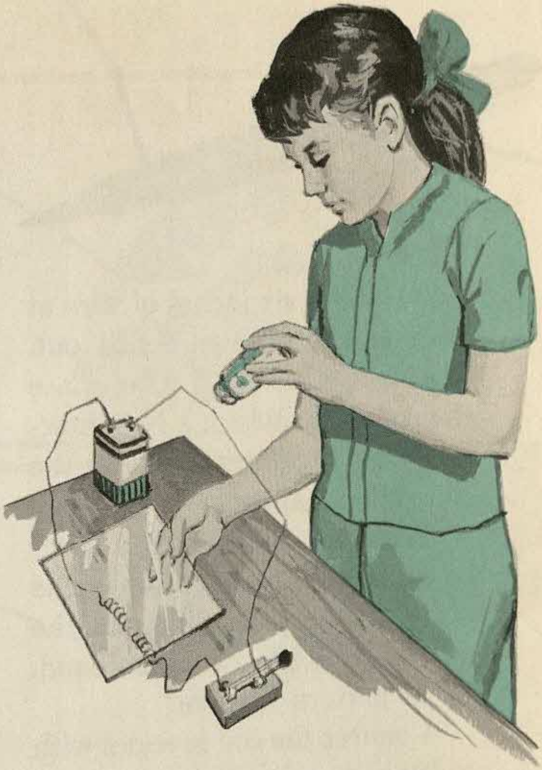
ACTIVITY Using copper wire, connect a dry cell and switch so you have a complete circuit when the switch is closed.

Put a compass beside the wire so that the wire and compass needle point in a N-S direction. Close the switch for a few seconds. What happens to the compass needle? Open the switch. What happens?

Put the compass under the wire. Close the switch. What happens?

Put the compass over the wire. Close the switch. What happens?

A Danish scientist, Hans Christian Oersted (OR-sted) (1777-1851), was the first to discover that a current-bearing wire caused a compass needle to move. Why was this discovery important?



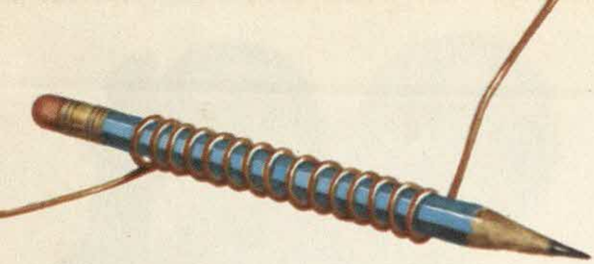
OBSERVE Take the dry cell, switch, and wire used in Activity 25. Insert one wire through cardboard. Support the cardboard on books. Close the switch. Shake iron filings around the wire. What does the pattern show?

DISCOVER Put four small compasses on the cardboard and close the switch. What happens? What did Oersted discover around a current-bearing wire? What happens when there is no current?

Oersted discovered that a wire carrying a current of electricity is surrounded by a magnetic field. The wire carrying the current seems to act like a magnet.

André Ampère read of Oersted's discovery. He wondered what would happen if the wire were made into a coil. Try it and see what Ampère discovered.

COMPARE Make a coil of wire by winding about two feet of bare bell wire around a pencil.



Leave about six inches of wire at each end. Pull the pencil out. This leaves a coil of wire. Place the coil on a table in a N-S direction. Put a compass next to the coil. What happens?

With one hand, hold a cardboard or glass plate on top of the coil. Sprinkle iron filings in the usual way with the other hand. What pattern is there?

Connect the coil in series with a dry cell and switch. Keep the coil in a N-S direction. Bring a compass near one end of the coil. Watch the compass. Close the switch for a few seconds. What happens? Try it again. Test the other end of the coil. What have you discovered? Hold one end of the coil in iron filings. What do you find out?

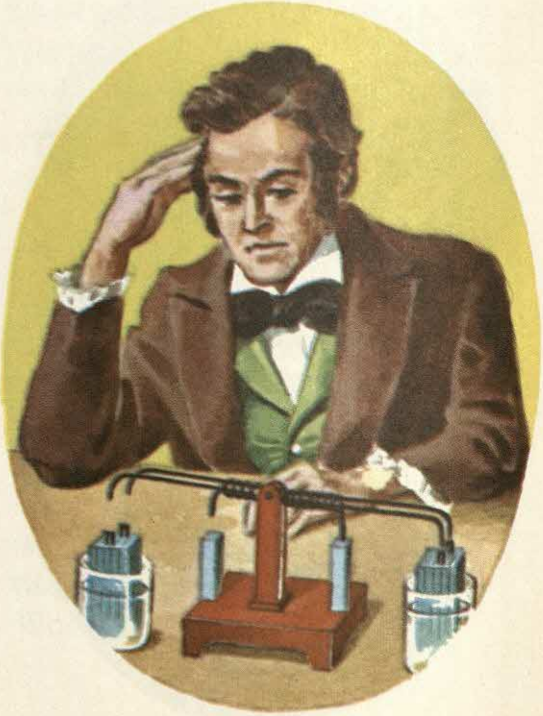
Hold the cardboard or glass plate on top of the coil. Then close the switch, and sprinkle the cardboard with iron filings. What pattern is there? Does the coil have a magnetic field? The coil acts like a magnet. Its magnetism depends on the electricity flowing through it, so it is called an electromagnet. How does increasing or decreasing the number of turns in the coil affect the magnetic field? Which produces a stronger magnetic field, thin or thick wire?

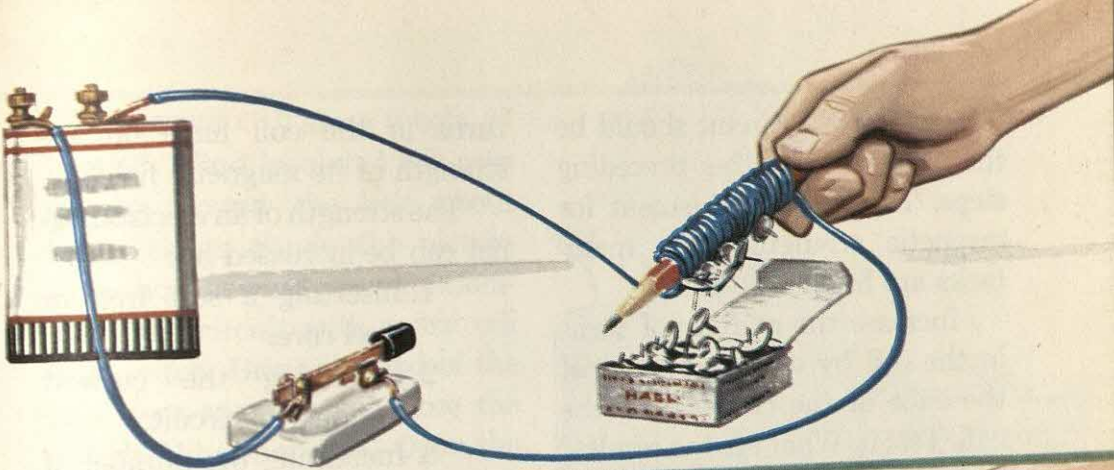
Is a simple coil of copper wire magnetic? Does it have a magnetic field? What happens when that same coil has an electric current through it? Is the current-carrying coil a temporary or permanent magnet? How could you check this? Does a current-carrying coil have magnetic poles? How could you find out?

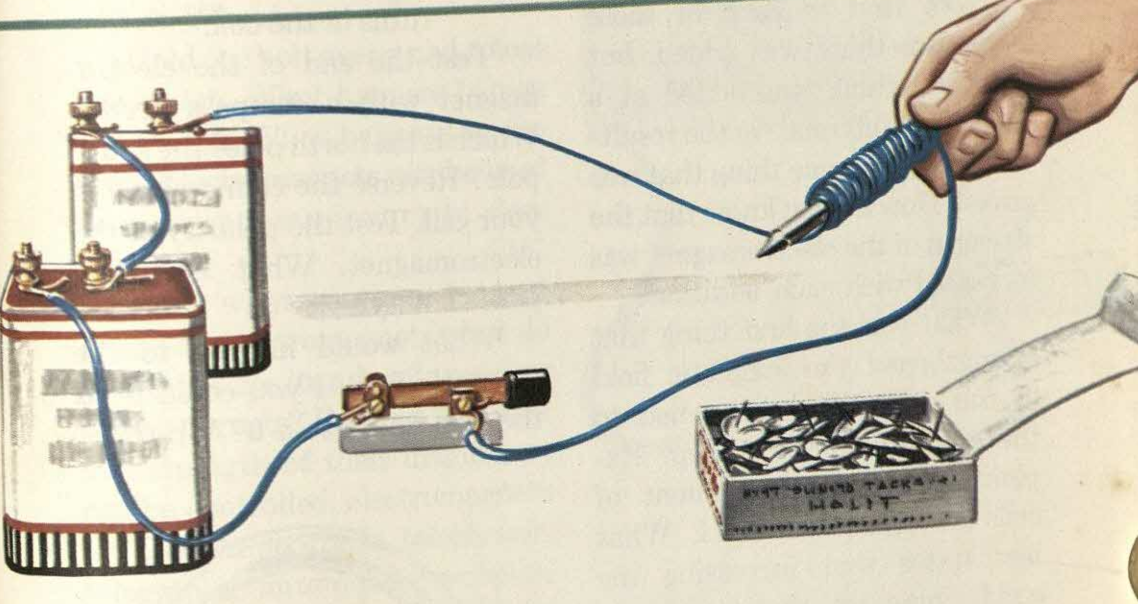
Electromagnets

Joseph Henry (1797-1878), an American scientist, used insulated wire to make an electromagnet.

DISCOVER Take four feet of insulated bell wire. Wind the wire







around a thick pencil about fifty times. Bare an inch of wire at each end. Complete a series circuit of coil, switch, and dry cell. Use tacks to test the strength of the electromagnet.

How can you test the strength of an electromagnet? Keep a record of the number of tacks attracted and held by the electromagnet in the following steps of this activity.

Close the switch. Touch the pile of tacks with the coil of the electromagnet. Move the coil a little to one side. Open the switch. How many tacks are attracted and lifted by the coil?

Wind the wire coil around a large, unmagnetized nail. Complete the circuit. How many tacks can be attracted and lifted by the coil this time?

Connect two cells in a series.

The rest of the circuit should be the same as in the preceding steps. Test this arrangement for magnetic strength. How many tacks are lifted this time?

Increase the number of turns in the coil by wrapping more of the ends of the coil around the nail. Test it. What are the results?

Note that in each of these steps something was added, but only one thing was added at a time. The difference in the results was due to the one thing that was added. How do you know that the strength of the electromagnet was increased with each addition?

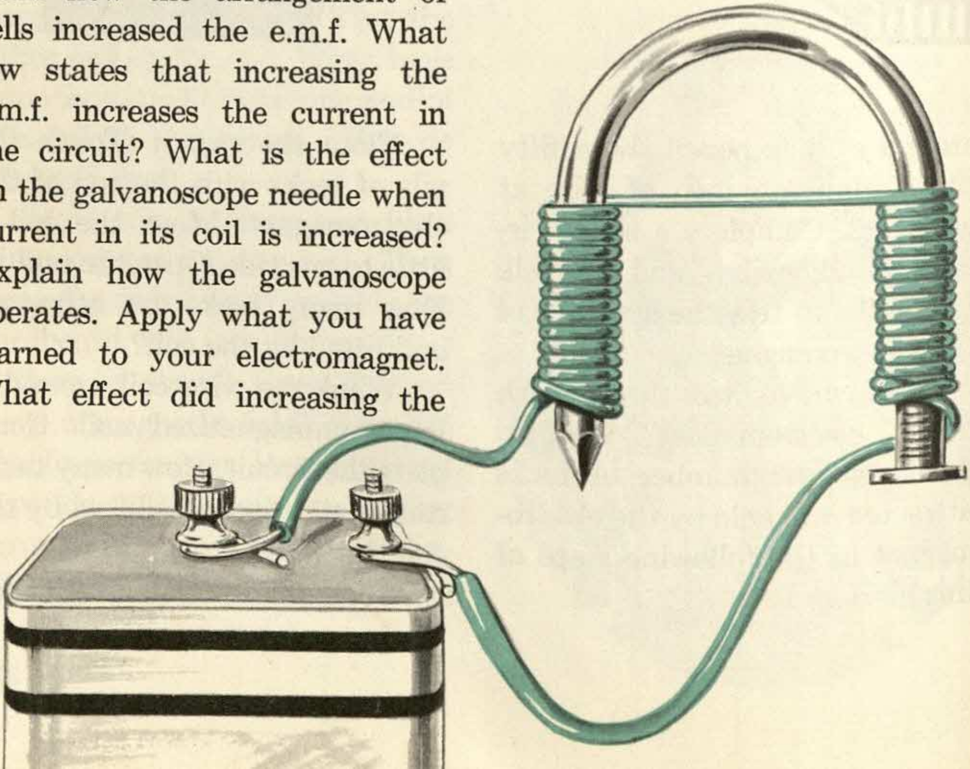
What was the first thing that strengthened the magnetic field of the coil? What happened to the e.m.f. in the next step? Explain how the arrangement of cells increased the e.m.f. What law states that increasing the e.m.f. increases the current in the circuit? What is the effect on the galvanoscope needle when current in its coil is increased? Explain how the galvanoscope operates. Apply what you have learned to your electromagnet. What effect did increasing the turns in the coil have on the strength of its magnetic field?

The strength of an electromagnet can be increased by:

1. Inserting a soft iron or steel core.
2. Increasing the current through its circuit.
3. Increasing the number of turns in the coil.

Test the end of the electromagnet with a compass needle. Which is the north pole? the south pole? Reverse the connections on your cell. Test the polarity of the electromagnet. What has happened? Why?

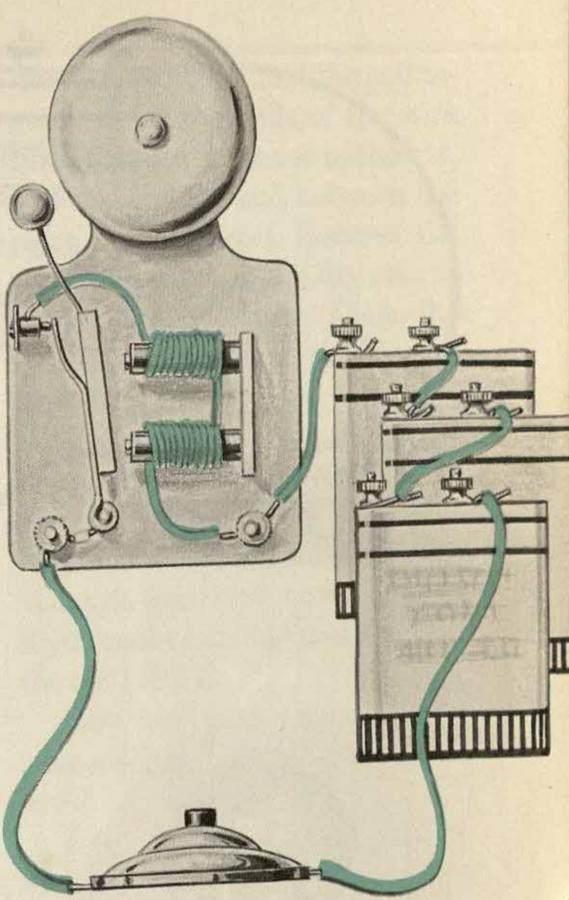
What would happen to the magnetic field if you could bend the iron nail into a U? Why?



OBSERVE Take a U bolt, 2″ by 1½″. Wind insulated bell wire closely around the bolt about thirty times. Study the picture to see how to wind the wire. Complete the circuit with a dry cell and switch. Bring the end of the bolt near some tacks. Close the switch. What happens? Open the switch. What happens?

Hold the bolt over a nail. Close the switch. What happens? Open the switch. What happens to the nail? Electromagnets can be used to pick up scrap iron or to close circuits. □□

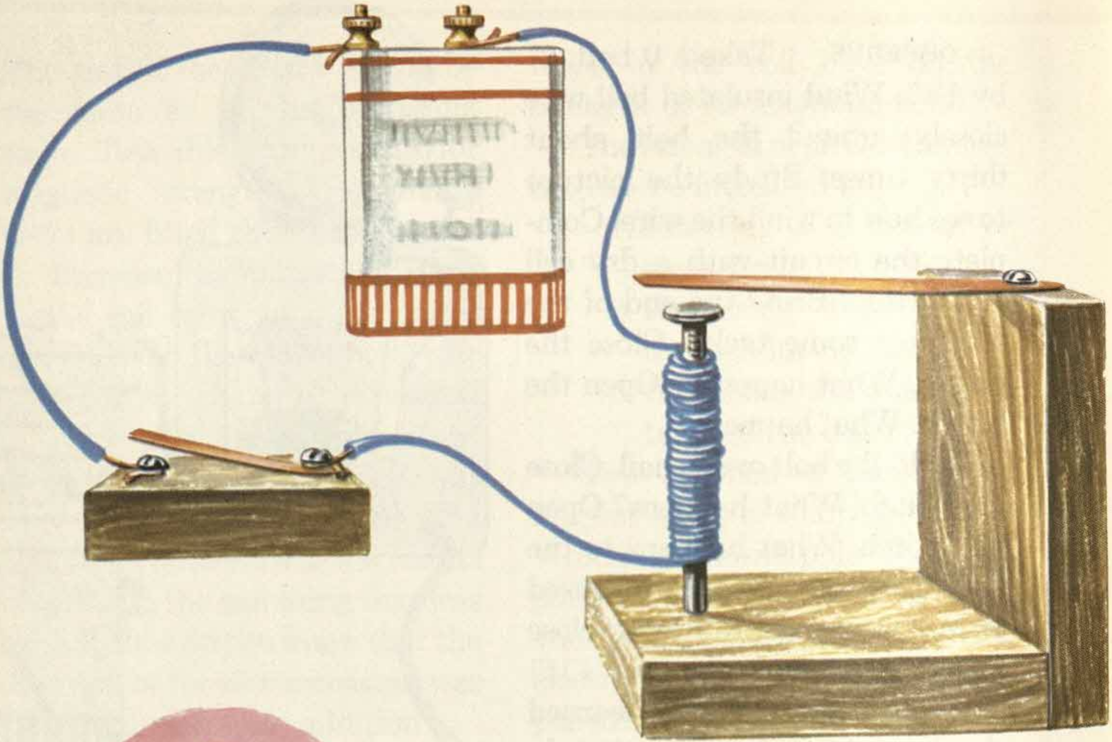
From what you have learned about an electromagnet, what do you think are its advantages over other magnets? Because the time and strength of their magnetism can be controlled, electromagnets are used in doorbells, telephones, telegraphs, automobile switches, loudspeakers, lifting magnets, electric motors, and many other electrical devices.



Uses of Electromagnets

Study the picture of the electric bell. Can you trace the circuit from the negative electrode to the positive electrode? What happens to the electromagnet when the switch is closed?

The soft iron bar to which the switch is attached is called the armature. A clapper is attached to the armature. What happens to the armature when the switch is closed? When the armature is pulled to the electromagnet, what happens to the spring? Why is the circuit broken? What happens to the armature when the circuit is broken? When the armature is released, the spring again moves to the contact screw, thus completing the circuit.



Examine the picture of a telegraph key and sounder. Samuel Morse, an American, built the first practical telegraph in 1844. Joseph Henry's work on the electromagnet made this invention possible. What happens when the key is closed? When it is opened? By spacing the opening and closing of the switch, a code can be sent. This code is made up of short pauses, the dots, and long pauses, the dashes. Try making a telegraph set like the one in the picture.

Electric Motors

A brief review of three important principles will help you understand how an electric motor works.

1. A current-carrying coil acts like a magnet. Such a coil is called an electromagnet because its magnetism is caused by electricity.

2. Like poles of a magnet repel each other; unlike poles attract each other.

3. The poles of an electromagnet change if the direction of the current changes.

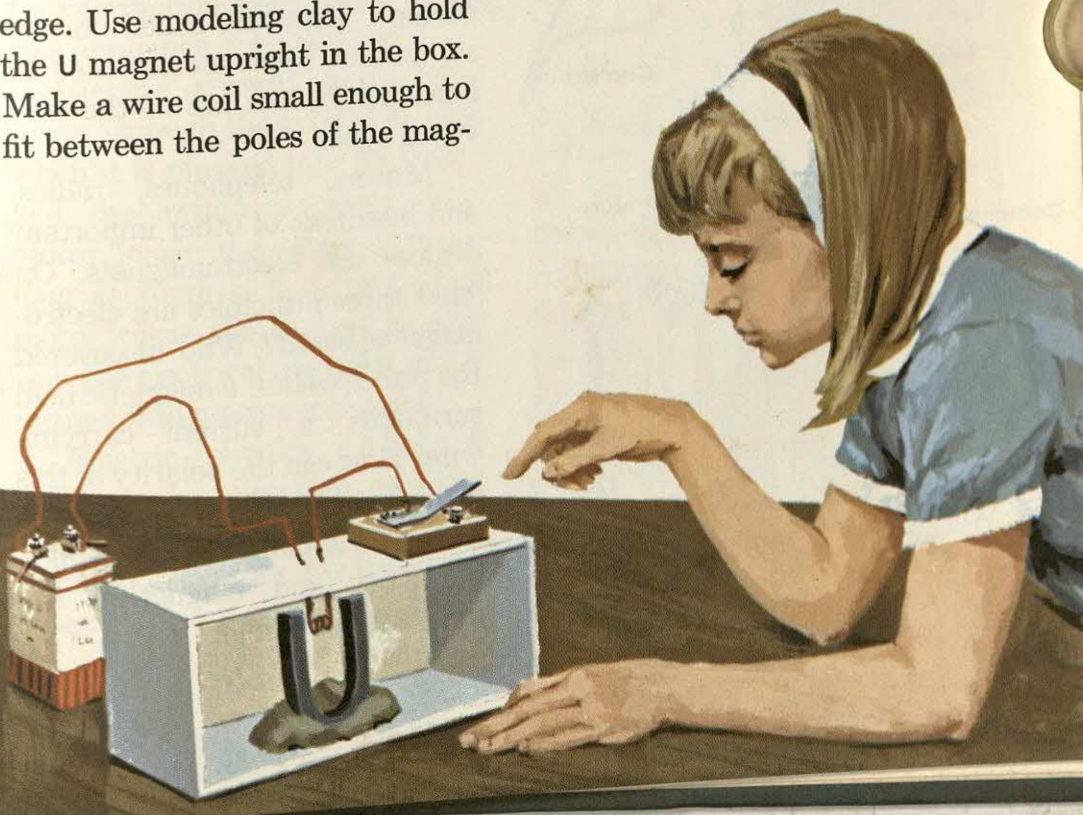
ACTIVITY Suspend a **U** magnet by a string over a compass needle. Spin the magnet. What happens to the compass needle? Why?

Take a shoebox and stand it on edge. Use modeling clay to hold the **U** magnet upright in the box. Make a wire coil small enough to fit between the poles of the magnet. Use string to hold the coil together. Pull the ends of the wire through holes in the top of the box, and suspend the coil between the poles of the magnet. Connect the wire to a switch and a dry cell, as shown in the picture. Close the switch. Open the switch. Observe what happens.

The coil turns until its N-pole is opposite the S-pole of the U magnet. Which pole of the coil is opposite the magnet's N-pole? What do you think would happen if you could reverse the current in the coil? Why?

How could you increase the magnetic strength of the coil of wire? □□

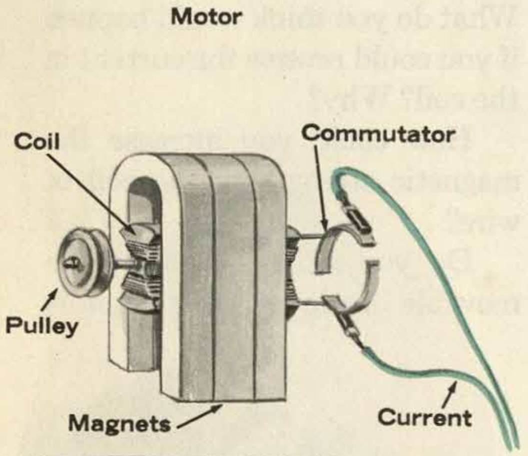
Do you remember what the movable bar in an electric bell is

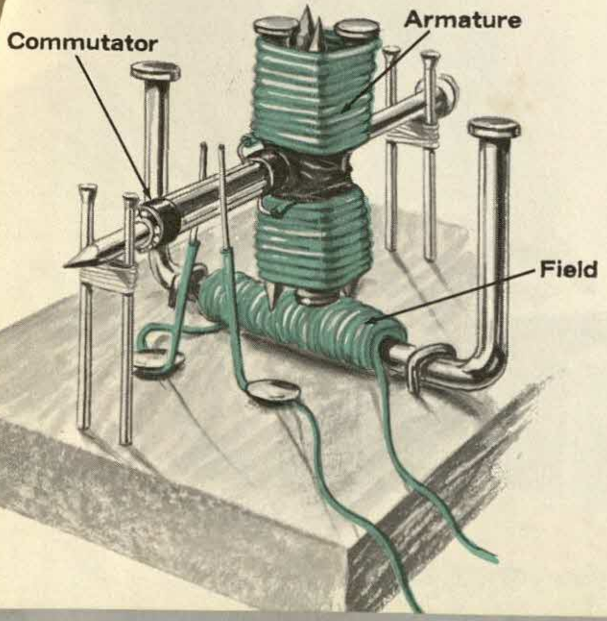


called? In an electric motor, the armature is an electromagnet which is free to spin.

There is also a fixed electromagnet, shaped to fit around the armature. This fixed electromagnet is called the field.

At each half-rotation of the armature, the direction of the current is reversed. Therefore, the poles change and the armature makes another half-rotation. This action is repeated over and over, causing the armature to spin. The arrangement for reversing the current in the armature is called the commutator. Your teacher may help you construct a toy motor.

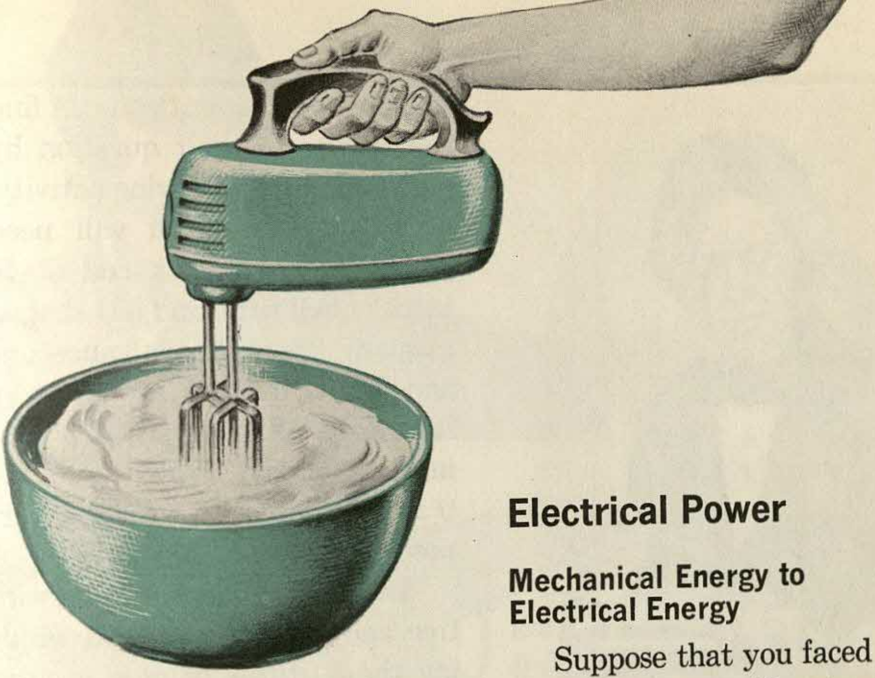




The type of motor which has been described is a D.C. motor. Why is it so called? What kind of current is supplied by chemical cells?

Is there another kind of electrical current? What kind of current powers your home and school? Do you know what the abbreviation A.C. stands for? Alternating current reverses its direction many times a second. Many motors are constructed so that they will operate on either current. These are called universal motors. Most motors used in home appliances are of the universal type.

Motors, telephones, radios, and hundreds of other important devices use electromagnets. On what three principles are electromagnets based? Who discovered the principle that a magnetic field surrounds a current-carrying wire? How can the polarity of this magnetic field be reversed? Recall some of the many ways in which electricity and magnetism are linked to serve man.



Electric Mixer

What is the name of the electrical appliance shown in the picture? For what is it used? How does it operate? What energy transformation takes place when this appliance is being used?

Electric current enters the mixer through the extension cord when it is plugged into an outlet and the switch is closed. The motor inside the mixer runs as long as there is a current. The motor turns the beater. In this way the electrical energy is transformed into mechanical energy.

Electric circuits provide a pathway for electrons to flow. This current is controlled by conductors, insulators, switches, and fuses.

Electrical Power

Mechanical Energy to Electrical Energy

Suppose that you faced a day —just one day—without any electric power in your home and school. In how many ways would your living be affected? Suppose that the amount of electric power available for home use was limited. Which electrical devices would you choose to use? Is the electric current from batteries limited in amount? Do chemical cells last indefinitely? Is the electric current in your home and school supplied by batteries?

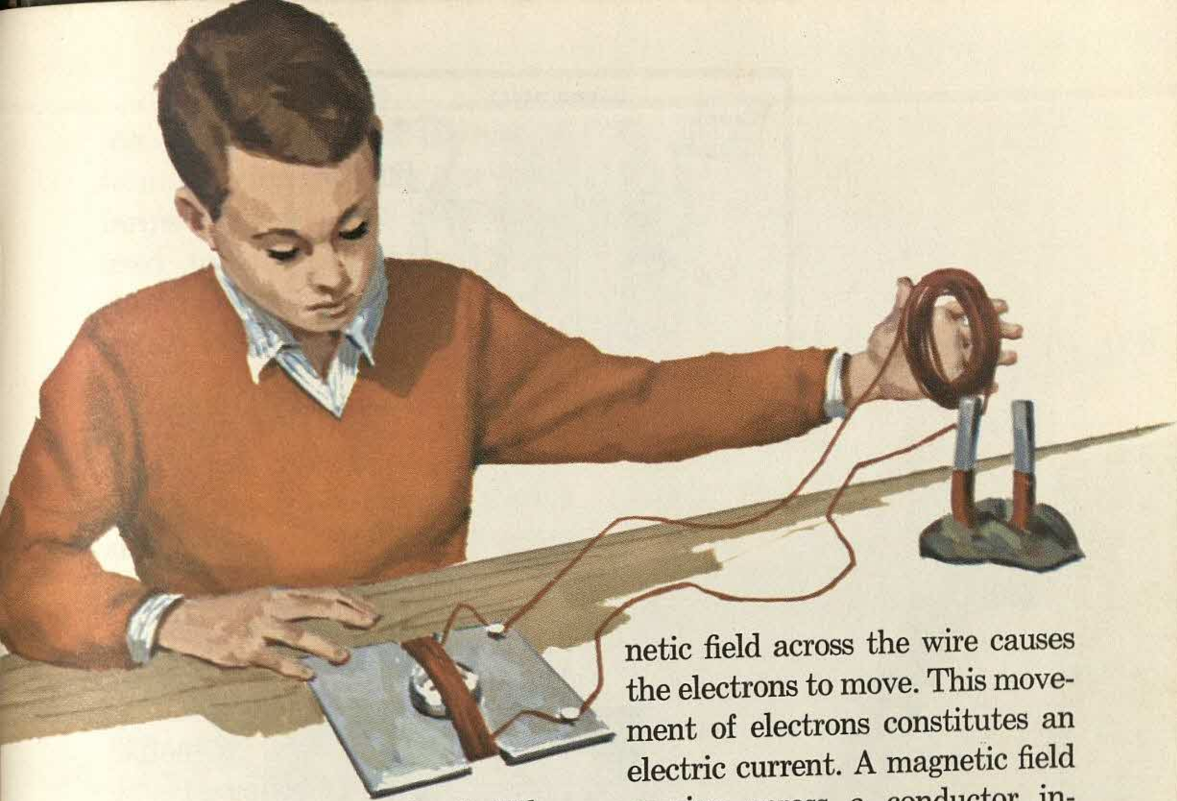
Some isolated communities depend upon batteries for their electricity. Telephone companies, hospitals, and other important services use batteries for emergencies. It is obvious, however, that batteries could not supply the electricity needed in large industrial cities.

Michael Faraday (1791-1867), an Englishman, and Joseph Henry were scientists who thought about Oersted's discovery that there is a magnetic field around a current-carrying wire. They reasoned in the following way. If an electric current in a conductor causes a magnetic field to surround the conductor, would a magnetic field put around the conductor cause an electric current to appear in its circuit? Although Faraday and Henry worked separately, both arrived at the same answer. You can find the answer to their question by performing the following activity.

DISCOVER You will need your galvanoscope, a coil of 50 turns of bell wire, and a U-shaped magnet. Keep the galvanoscope and the U magnet as far away from each other as possible during this activity. How would the U magnet interfere with the purpose of the galvanoscope?

Leave about two feet of wire free, and then make the coil, winding the 50 turns of wire around a card. Leave about two feet of wire at the end of the coil. Bare one inch at the free ends. Twist each of these ends with an end of the galvanoscope in tight connections. Be sure to turn the galvanoscope coil so that it rests in the same direction as the arrow of the compass. Do you have a complete circuit? Is there a current in the circuit now? How do you know there is no current? What name is given to a coil which is wrapped around a magnetic core?

Use modeling clay to hold the U magnet upright. Hold the coil of wire over one pole of the magnet. Slip the coil around the pole. Watch the needle of the galvanoscope. Remove the coil from the magnet with a *quick* motion. How does the needle move? Try slip-



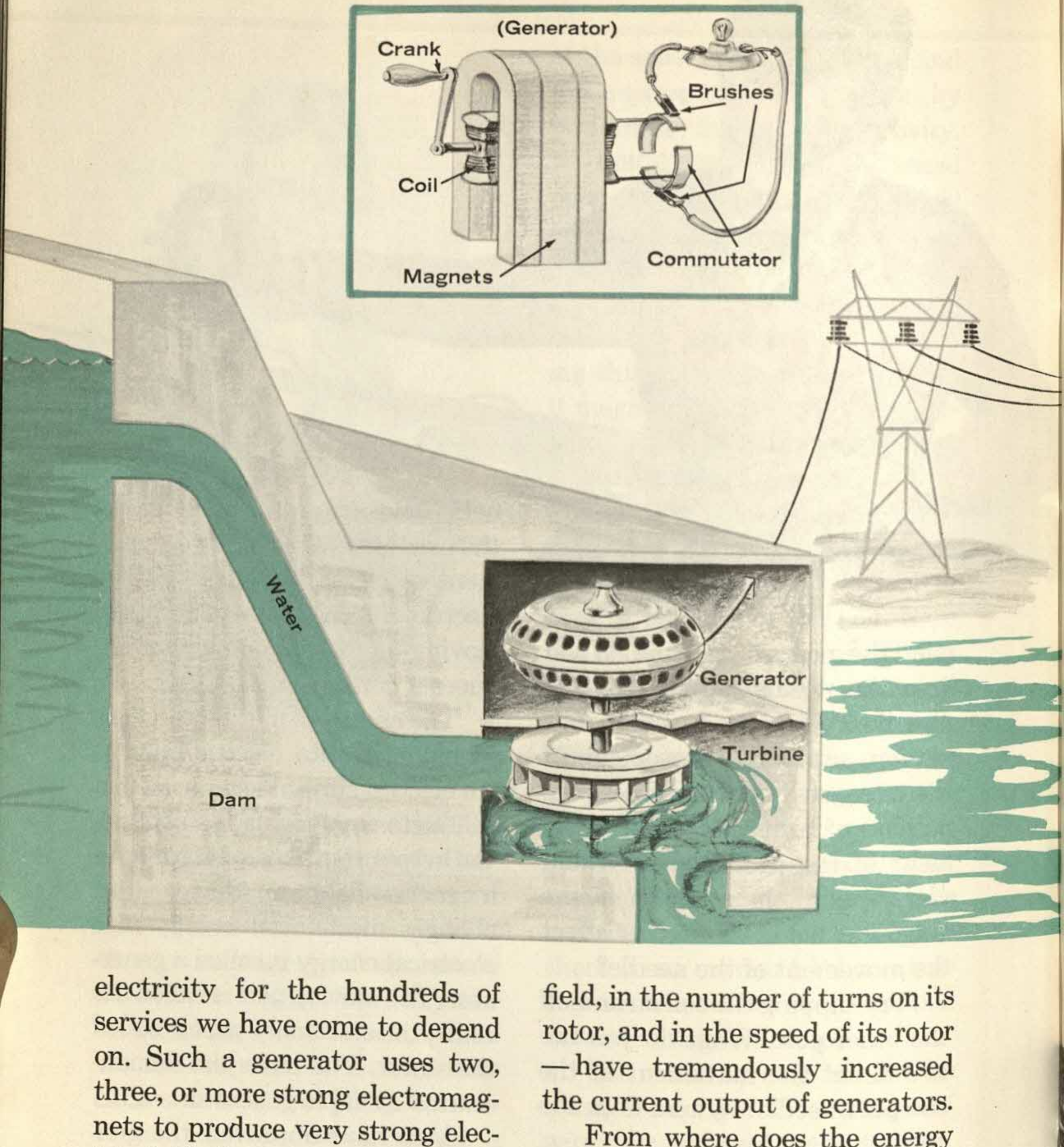
ping the coil on and off. When does the needle move? In what direction? Does the speed of your motion affect the movement of the compass needle? Does the number of turns affect the movement of the needle? How could you increase the strength of the magnetic field? Does this affect the movement of the needle?

Try slipping the coil on and off the other pole. What do you notice about the movement of the compass needle? Where does the current come from?

Since electrons are not flowing into the circuit from an outside source such as a chemical cell, they must come from inside the circuit. The passing of the magnetic field across the wire causes the electrons to move. This movement of electrons constitutes an electric current. A magnetic field moving across a conductor induces a current in its circuit.

The energy of motion can thus be changed into electric energy. An electric current is induced in a conductor by moving the conductor across the lines of force in a magnetic field. A device that changes mechanical energy into electrical energy is called a generator. The moving part is called the rotor; the stationary part is called the stator. You have just demonstrated a simple generator. □□

Men have improved the generator until it can provide electric power for a city of over five hundred thousand people. This means that one generator in a local electric generating station can supply



electricity for the hundreds of services we have come to depend on. Such a generator uses two, three, or more strong electromagnets to produce very strong electric fields. It may have as much as thirty miles of copper wire wound on its rotor. Its rotor may spin at very high speeds. All of these improvements—in the strength of its field, in the number of turns on its rotor, and in the speed of its rotor —have tremendously increased the current output of generators.

From where does the energy come to rotate the rotor at such high speeds? You used mechanical energy to move the rotor of your generator. The rotor of an automobile generator is turned by the engine, which uses the energy from burning gasoline. On some farms the energy of the wind is used to turn a windmill. The windmill turns the rotor of a generator to supply electric power to the farm.

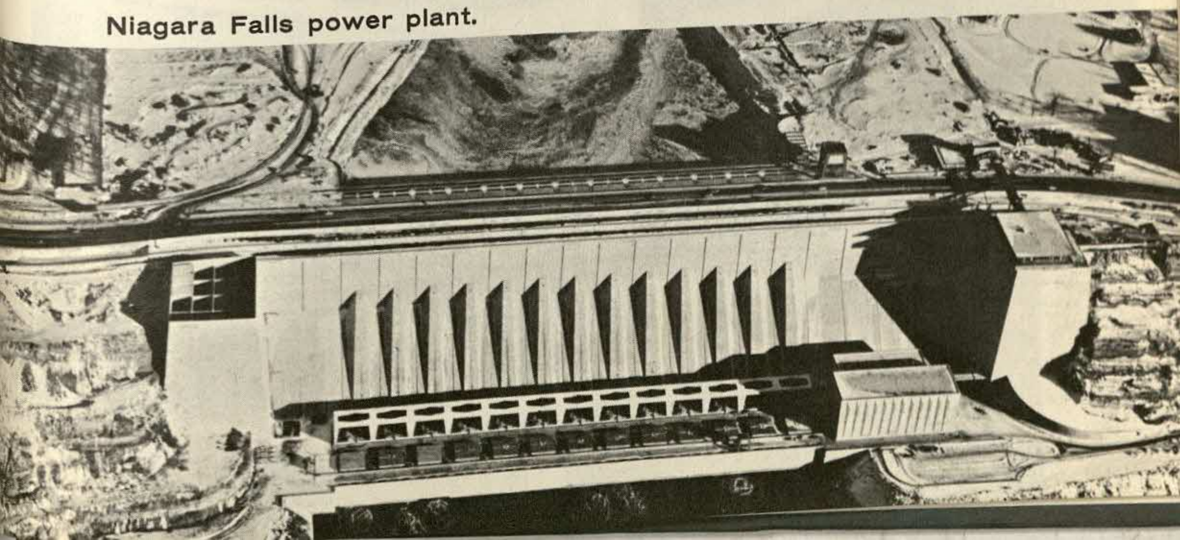
In commercial generating plants, the force of water, steam, or a hot gas is used to turn wheels similar to water wheels. A series of stationary and movable wheels is called a turbine. A turbine is used for generating electricity. The movable wheel of a turbine is called a rotor; the stationary wheel is called a stator. The stator directs the water, steam, or gas flow through the turbine. The rotor turns a shaft. This rotating shaft turns the rotor of a generator.

At the base of Niagara Falls is a plant which converts the energy of falling water to electrical energy. Such a plant is called a hydroelectric plant. Look at the picture. The rotor of the turbine is attached to the shaft. On the other end of the shaft is the generator rotor. What work does the falling water do? What work is done by the turning shaft? What energy conversion takes place in the generator?

In steam turbine plants, coal or oil is burned. What energy transformation takes place? The heat energy is transferred to water. What change of state takes place? The blast of steam may travel at a speed of twelve hundred miles an hour through the turbine. What energy transformation takes place? The mechanical energy of the turbine is transferred to the rotor of the generator. Some energy is wasted along the way because no machine is perfectly efficient.

Atomic power plants are like steam turbine plants. Instead of using coal or oil as fuels to heat water into steam, they use an

Niagara Falls power plant.

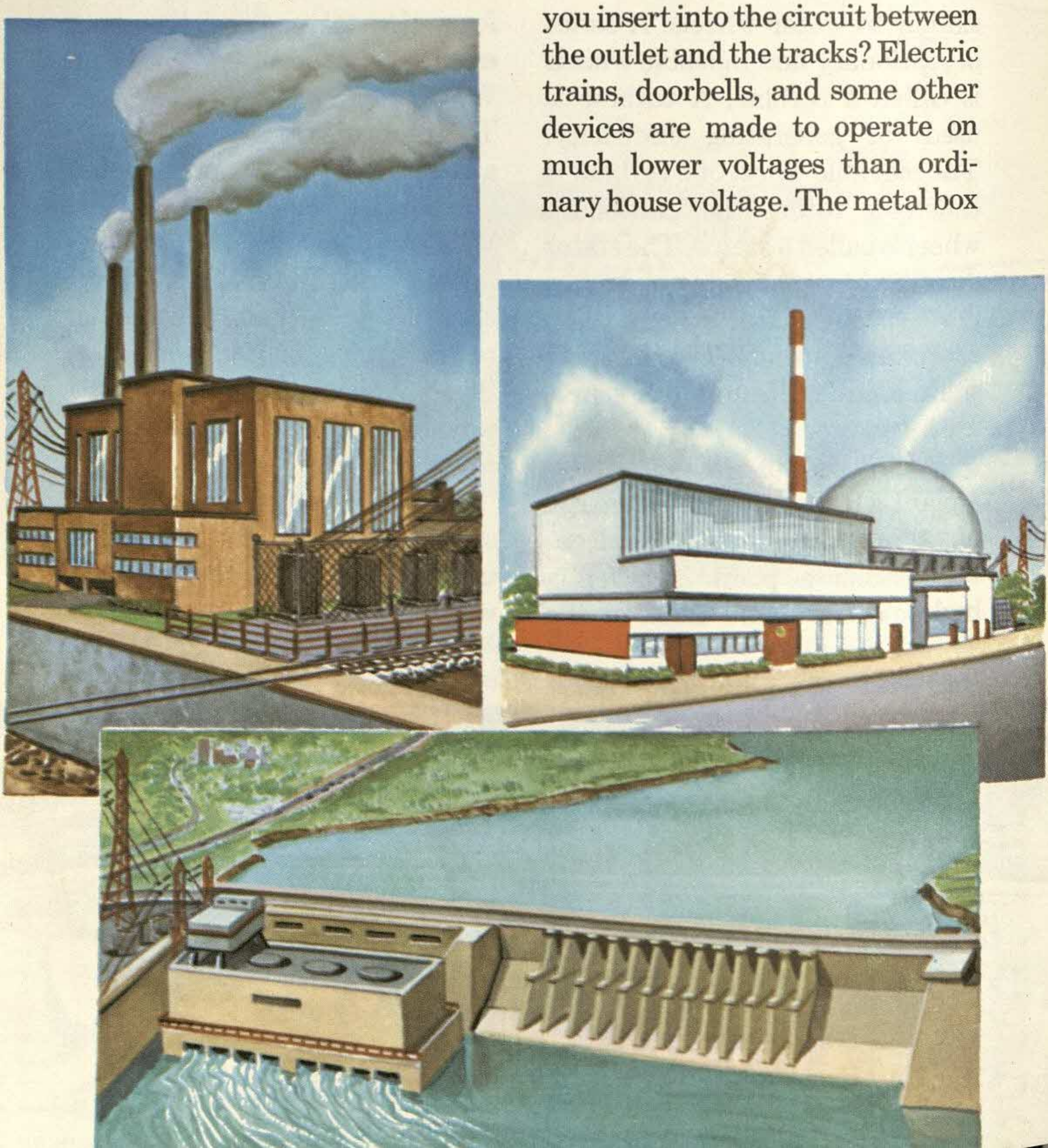


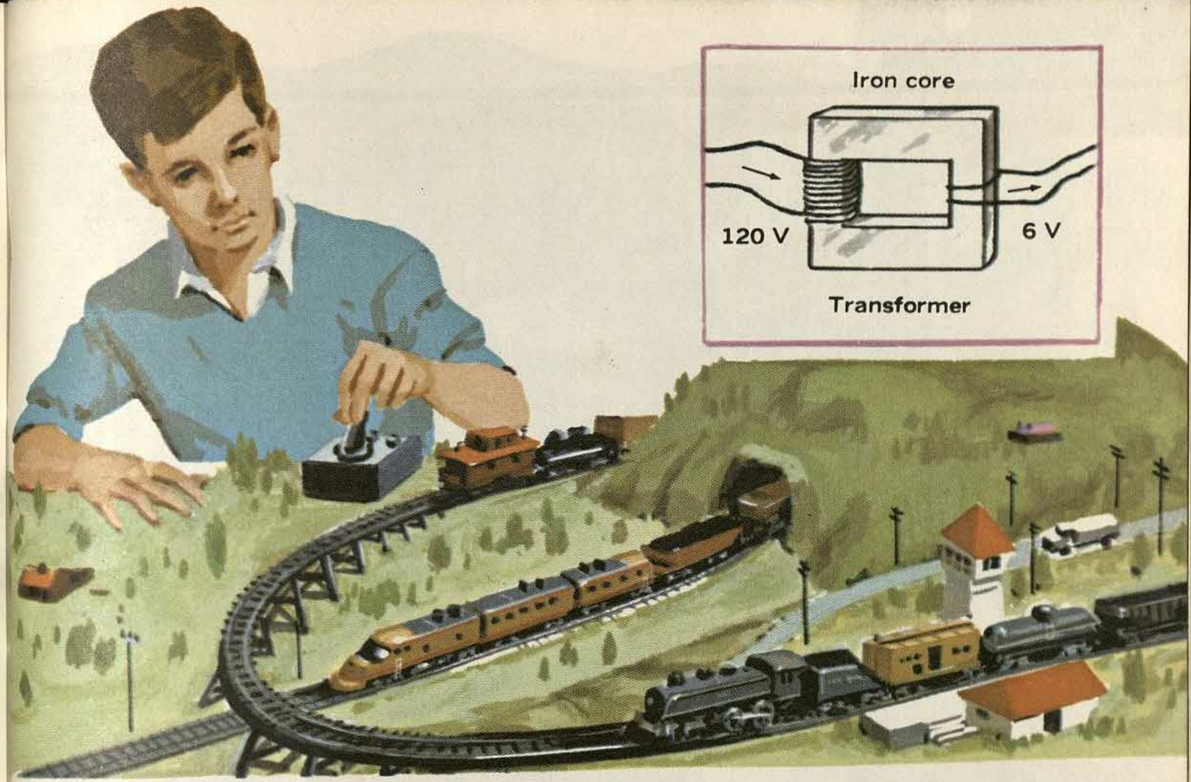
atomic fuel in a nuclear reactor furnace.

The operation of all generators, no matter how complex, is based on the principle discovered by Michael Faraday and Joseph Henry. Both generators and motors are possible because of the inter-relationship of magnetism and electricity.

Electrical Energy to Electrical Energy

Many of you have seen or played with a set of electric trains. They are powered by the energy from an electrical outlet in your home. What kind of current is used? Do you plug the track circuit directly into the outlet? What is the small metal box which you insert into the circuit between the outlet and the tracks? Electric trains, doorbells, and some other devices are made to operate on much lower voltages than ordinary house voltage. The metal box





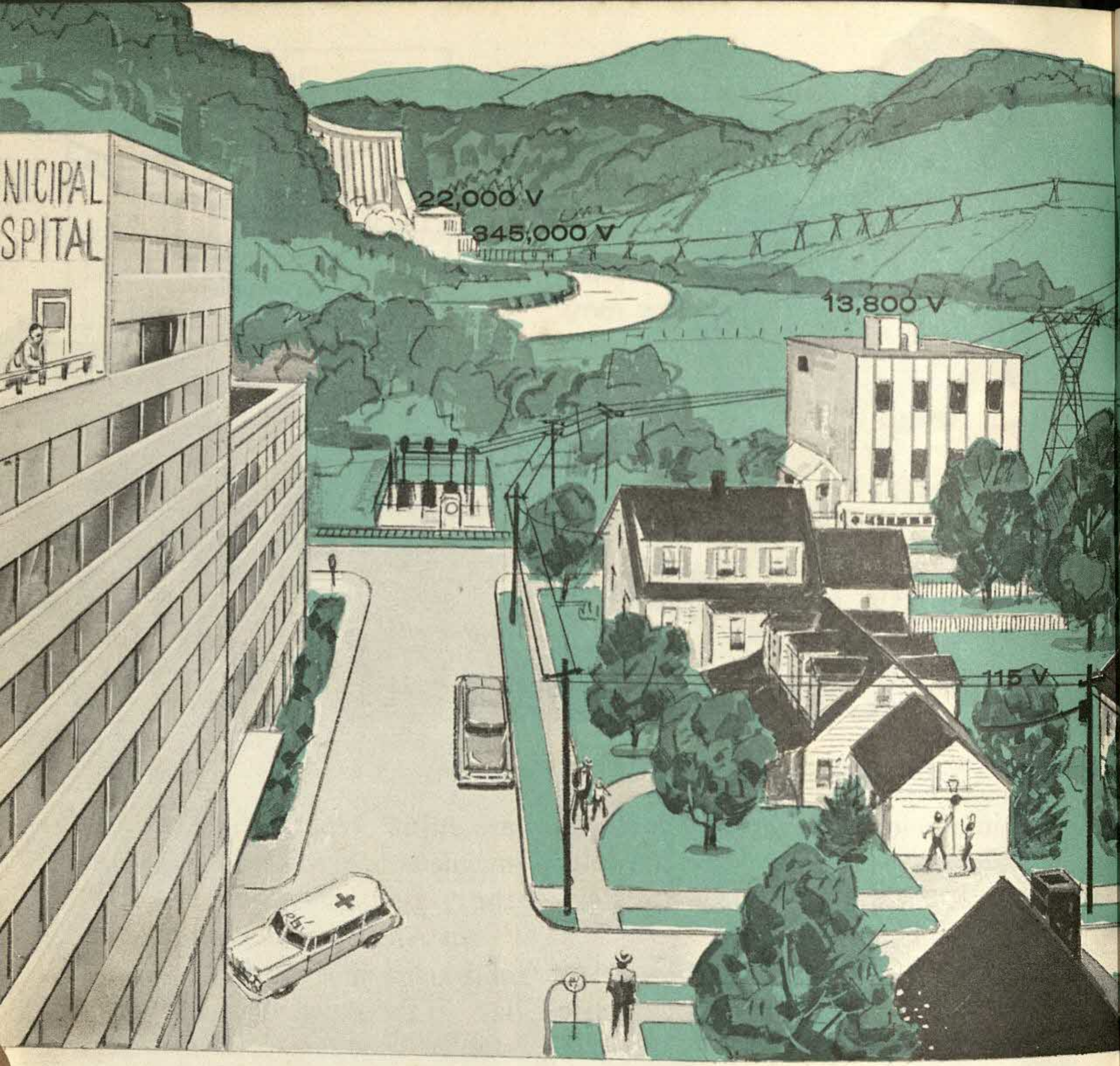
in an electric train set contains a device for cutting down the voltage. This device is called a step-down transformer.

In general, house voltage varies from 110v to 120v. Toy electric trains usually require 6v. Look at the diagram of a step-down transformer. There are two coils of wire, one larger than the other. The first coil is called the primary coil. When the 120v A.C. enters the primary coil, what is induced around the coil?

The second coil is called the secondary coil. What happens in the secondary coil as the magnetic field from the primary coil sweeps around it? What happens to the magnetic field around a coil when the current is reversed?

In A.C. current the direction of the current is constantly changing, so the magnetic field is constantly changing. The changing magnetic field sweeps back and forth through the secondary coil many times a second. A current is induced in the secondary coil. In a step-down transformer, which coil has fewer turns? In which coil will the voltage be less?

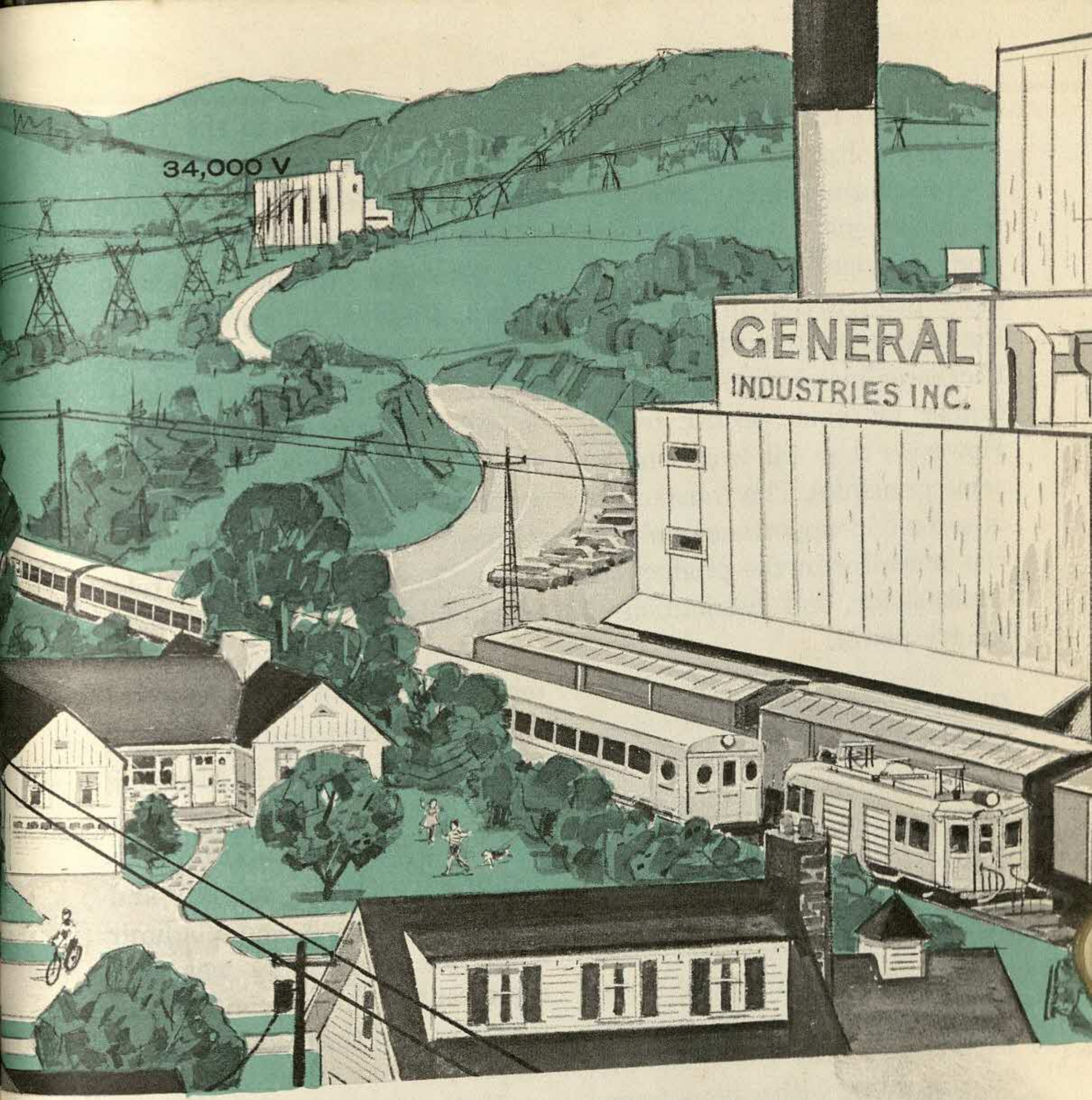
What do you think is the purpose of a step-up transformer? In a step-up transformer, which coil has more turns?



Electric Power Transmission and Distribution

Electrical energy is transmitted over long distances at very high voltages. In this way less energy is wasted through the heating of the wires. Both step-up and step-down transformers play very important parts in the transmission of electric power from a generating plant to your home.

The generator in the hydroelectric plant may produce a current with an e.m.f. as high as 22,000 volts. However, an even greater electromotive force is needed to transmit electric power over long distances. Therefore, a step-up transformer just outside the plant increases the voltage to



as much as 345,000 volts. At the distribution station the e.m.f. is stepped down to 34,000 volts. This is stepped down again to 13,800 volts just before the electric current enters the distribution substation. Some large industrial plants receive their power right from this substation. Railroads, hospitals, and other users of voltages higher than house voltage have transformers which take care of their needs. Pole transformers step down the voltage from the substation to about 115v for your home. There is a transformer in your television set which steps up the voltage to 10,000v or more. What are some other appliances in your house that require transformers to supply their voltage needs?

Transformers are of many different designs. They vary in size from the giant maze outside the power plant, to the can hanging on the poles that support your electric power lines, to the small transformer for your electric trains. However, they all work on the same principles. The transformer is second in importance only to the generator in the production, transmission, and distribution of electric power.

Direct Transformation to Electrical Energy

Turbine generators are huge, bulky machines. At the Niagara Power Project the rotor of each of the thirteen generators weighs five hundred tons. Much work must be done to turn these parts. Much energy is lost because of friction and heat. Scientists are experimenting with ways of transforming mechanical, heat, light, and nuclear energy directly to electrical energy.

Electronics

Faraday and Henry, pioneers in electricity, learned how to control electric current in wires. The work of many men in the twentieth century has developed a new branch of electrical knowledge which deals chiefly with the flow of electrons through vacuum tubes, gas-filled tubes, and other devices, rather than through wires. This field of knowledge is called electronics. Electronics makes possible such modern wonders as television, transistor radios, electronic computers, radar, and long-distance telephone lines.

You may be interested in reading about some of the pioneers in electronics. Find out more about the lives of such men as Marconi, who invented the first wireless, Lee De Forest, an important inventor in wireless telegraphy and radio broadcasting, and Vladimir Zworykin, whose work was very significant in the development of television and the electron microscope.

Today, many research teams are studying ways of controlling the electron. Progress in this area is being made rapidly, and you may want to investigate current magazines, newspapers, and library books for up-to-date information. Look under such headings as solar energy, automation, business machines, and electronics.

THINK

Many automobiles have a small rubber strip which dangles down and touches the ground. What explanation can you suggest for this?

Many times the case from old batteries ruins flashlights. Can you explain why?

During the Christmas season, many of you have Christmas lights. Examine a string of them carefully. Are they connected in series or parallel? Which would be better?

People sometimes place pennies in their fuse boxes rather than buy a new fuse. Why is this a dangerous practice? What might result?

Why do some plugs have three prongs while others have two?

Thomas Edison spent many years trying to form a vacuum in a glass tube. Why was this necessary to make a successful, long-lasting bulb?

What is the advantage of fluorescent lights over other types?

A student observed that a Canadian nickel is magnetic while a U.S. nickel is not. What explanation can you give for this difference?

PROJECT

Wire a two-story doll house. Install electric lights, an electric door bell, switches, and fuses.

GLOSSARY

air mass (ayr mas). A large body of air having fairly uniform temperature and humidity throughout.

algae (AL-jee). One-celled plants that contain chlorophyll.

alternating current (AWL-ter-*nay*-ting KER-ent). An electric current that reverses its direction many times each second.

altimeter (al-TIM-uh-ter). An instrument for determining distance above sea level.

altitude (AL-tih-tood). Height above sea level.

ampere (AM-peer). A unit for measuring the strength of an electric current.

amphibian (am-FIB-ee-un). An animal that lives part of its life on land and part in water.

anemometer (an-uh-MOM-uh-ter). An instrument for measuring the speed of wind.

annuals (AN-yoo-l'z). Plants that live for only one season.

antennae (an-TEN-ee). The feelers on the heads of certain animals.

anticyclone (AN-tee-*sy*-klohn). A large mass of high-pressure air.

armature (AHR-muh-choor). A piece of soft iron connecting the poles of a magnet; or the movable part of an electric generator or motor.

atmosphere (AT-mus-feer). The mass of air surrounding the earth.

auxin (AWK-s'n). A plant substance that affects growth.

bacteria (bak-TEER-ee-uh). A group of very tiny one-celled plants.

barometer (buh-ROM-uh-ter). An instrument for measuring air pressure.

battery (BAT-tuh-ree). A group of two or more electric cells connected together to furnish electric current.

biennials (by-EN-ih-alz). Plants that require two years to complete their life cycle.

buoyancy (BOY-un-see). Upward force which a liquid or gas exerts on bodies placed in them.

capacitor (kuh-PAS-ih-ter). A device for storing charges of static electricity.

carapace (KAIR-uh-pase). The hard outer shell of certain animals.

carnivore (CAR-nuh-vor). A meat-eating animal.

cellulose (SEL-yuh-lohs). The chief material in the cell walls of plants.

chlorophyll (KLAW-ruh-fil). The green coloring matter of plants.

chloroplast (KLAW-ruh-plast). A tiny body in a plant cell which

---

To aid in pronunciation all primary stress syllables have been put in capital letters and the secondary stress syllables are in italics.

contains the chlorophyll.

cilia (SIL-ee-uh). Hairlike projections found on certain one-celled animals such as the paramecium.

circuit (SER-ket). The complete path of an electric current.

cirrus clouds (SIH-rus klowdz). Thin, wispy clouds high in the stratosphere.

commutator (KOM-myuh-*tay*-ter). In an electric motor, an arrangement for reversing the current in the armature.

condensation (kon-d'n-SAY-sh'n). The process by which a gas or vapor changes into a liquid.

condenser (kon-DEN-ser). A device for storing charges of static electricity.

conductor (kon-DUK-ter). A material through which electricity will pass.

constellation (KAHN-stuh-*lay*-sh'n). A group of stars which seem to form a pattern in the sky.

convection currents (kun-VEK-shun KER-entz). Circular movements of heated parts of a liquid or gas.

cumulus clouds (KYOOM-yoo-lus klowdz). Large, fleecy clouds that form at moderate heights.

cycle (SY-k'l). A series of actions or events which are repeated regularly and in the same order.

cyclone (SY-klohn). A large mass of low-pressure air.

density (DEN-sih-tee). The weight of a unit volume.

dew point (dyoo poynt). The temperature to which air must be cooled in order for the water vapor which it contains to be changed back to a liquid.

diffraction grating (dif-RAK-shun GRAY-ting). A system of close, equally distant, and parallel lines ruled on a polished surface, used to produce a spectrum.

direct current (dih-REKT KER-ent). An electric current that flows only in one direction.

electric cell (eh-LEK-trik sel). A device for changing chemical energy to electrical energy.

electric charge (eh-LEK-trik charj). The quantity of electricity on an object; an excess or lack of electrons.

electric current (eh-LEK-trik KER-ent). Moving electricity; a continuous flow of electrons through a conductor.

electricity (eh-lek-TRIH-sih-tee). A form of energy produced by a flow of electrons through matter.

electric field (eh-LEK-trik feeld). The space around a charged object in which its force is felt.

electrode (eh-LEK-trohd). The terminal by which a current leaves or enters an electric cell.

electrolyte (eh-LEK-truh-lyte). A solution that conducts an electric current.

electromagnet (eh-LEK-troh-*mag*-net). A magnet made by sending an electric current through a coil of wire wound

around a solid core of iron.
electromotive force (eh-LEK-troh-*moh*-tiv fors). The force, in volts, that causes electrons to flow in an electric circuit.
electron (eh-LEK-trahn). A negatively charged particle present in every atom.
electroscope (eh-LEK-truh-skohp). A device used to detect and identify electric charges.
embryo (EM-bree-oh). The young plant contained in a seed.
evaporation (ee-*vap*-O-RAY-shun). Change of a liquid to a gas.
exoskeleton (EK-soh-skel-uh-tun). The hard covering on the outside of some animals.
exosphere (EK-soh-sfeer). The part of the atmosphere from about 300 miles above the earth to the upper edge of the atmosphere.

fertilization (*fer*-til-ih-ZAY-shun). The union of a sperm nucleus with an egg nucleus.
filament (FIL-uh-ment). In an electric bulb, the fine wire that becomes heated and gives light.
front (frunt). An area of atmospheric disturbance formed when two air masses meet.
fungi (FUN-jy). Simple plants which contain no chlorophyll.
fuse (fyooz). A piece of easily melted metal placed in an electric circuit to break the circuit if too much current flows in it.

galvanoscope (gal-VAN-uh-skohp). An instrument for measuring a small electric current.
gas (gas). A state of matter that has no definite shape or volume.
generator (JEN-uh-*ray*-ter). A device which converts mechanical energy to electrical energy.
geotropism (jee-OT-ruh-piz'm). The response of plant roots to the force of gravity.
germination (*jer*-mih-NAY-shun). The start of growth in a seed.
gill (gil). The breathing organ of a fish.
gnomon (NOH-mahn). The upright triangular piece on a sundial.
gravity (GRAV-ih-tee). The attraction of the earth for all matter on or near it.
gravity pressure (GRAV-ih-tee PRESH-'r). Pressure caused by the weight of gases or liquids.
guard cells (gahrd selz). Cells that regulate the size of stomata in leaves.

herbivore (HER-buh-vor). A plant-eating animal.
hibernation (*hy*-ber-NAY-shun). Spending the winter in an inactive condition.
high (hy). A large mass of high-pressure air; an anticyclone.
humidity (hyoo-MID-ih-tee). The amount of moisture in air.
hydrotropism (hy-DROT-ruh-piz'm). The response of plant roots to water.
hygrometer (hy-GROM-uh-ter). An instrument for measuring the humidity or amount of moisture in the air.

ionosphere (ey-AHN-us-sfeer). The part of the atmosphere which extends from 50 to about 300 miles above the earth.

ions (EY-unz). Atoms in which electrons have been added or removed so that the atoms are electrically charged.

induction (in-DUK-shun). Producing an electric current in a conductor by moving the conductor across magnetic lines of force.

insulator (IN-suh-*lay*-ter). A material that prevents the passage of electricity.

invertebrates (in-VUR-tuh-braytz). Animals that have no backbone.

larva (LAHR-vah). A wormlike stage in the metamorphosis of insects.

lenticels (LENT-uh-selz). Openings in the stems of plants through which the plants "breathe."

lightning (LYT-ning). An electrical discharge between clouds or between clouds and the earth or objects on the earth.

light year (lyt yeer). The distance which light travels during a year.

lodestone (LOHD-stohn). A rocklike natural substance which has magnetic qualities.

low (loh). A large mass of low-pressure air; a cyclone.

magnet (MAG-net). A substance which attracts iron, nickel, and certain other metals.

magnetic field (mag-NET-ik feeld). The region around a magnet in which its magnetic force acts.

magnetism (MAG-nuh-tiz'm). The property of certain substances to act as magnets.

manometer (mun-OM-uh-ter). An instrument for measuring the pressure of air and other gases.

mass (mas). The amount of matter in an object.

metamorphosis (*met*-uh-MOR-fuh-sis). The body changes certain animals pass through in developing from an egg to an adult.

meteorology (mee-tee-er-OL-uh-jee). The scientific study of weather.

naturalist (NACH-er-uh-list). A scientist who studies nature in the field rather than in the laboratory.

nonelectrolyte (non-eh-LEK-truh-lyte). A solution that will not conduct an electric current.

nymph (nimf). An immature stage of some insects between egg and adult.

occluded front (ok-KLYOO-duhd frunt). The "closed in" front that occurs when a warm air mass is lifted between two cold air masses.

omnivore (AHM-nuh-vor). An animal that eats both plants and animals.

open circuit (OH-p'n SER-ket). A broken or incomplete circuit.

operculum (oh-PUR-kyu-lum). The gill covering of fishes.

orbit (OHR-bit). The regular path of a body in space which moves around another body.

ovary (OH-vah-ree). The female reproductive organ.

parallax effect (PAIR-uh-laks uh-FECT). The apparent shift in the location of an object when it is viewed from different positions.

parasite (PAIR-uh-syt). An organism that lives and grows only on or in another organism.

payload (PAY-lohd). The load a vehicle can carry excluding its own weight and the weight of its engine and fuel.

perennials (pur-EN-ih-alz). Plants that live for more than two years, sprouting year after year from the old roots or stems.

petiole (PET-ee-ohl). The small flexible stem of a leaf.

photosynthesis (*fo*-to-SIN-thus-sis). The process by which green plants make sugars and starches in the presence of light.

phototropism (fo-TOT-truh-piz'm). The movement which plants make toward a source of light.

pistil (PIS-tihl). Female reproductive organs of a flower consisting of the ovary, the style, and the stigma.

planetary winds (PLAN-uh-*tayr*-ee windz). Winds that blow over large areas of the earth.

plankton (PLANGK-t'n). The tiny plants and animals that make up the primary source of food in the oceans.

pole (pohl). One of the ends of a magnet where its magnetism is concentrated.

pollen (PAHL-l'n). The powdery substance produced by the male reproductive organs of plants, containing the male sex cells.

pollination (*pahl*-ih-NAY-shun). Transfer of pollen from the stamen to the pistil of a flower.

potential difference (po-TEN-sh'l DIF-uh-rens). The difference in the electrical condition between two objects.

precipitation (preh-sip-ih-TAY-shun). Any form of water, liquid or solid, which condenses and falls from the air.

primary cell (PRY-muh-ree sel) An electric cell in which the chemical action cannot be reversed.

primary coil (PRY-muh-ree coyl. A coil of wire connected to a source of electric current.

pupa (PYOO-puh). An inactive stage in the metamorphosis of an insect.

radar (RAY-dahr). A system for detecting distant objects by reflections of very short radio waves.

radii (RAY-dee-eye). Straight lines from the center of a circle to its circumference.

radio astronomy (RAY-dee-oh uh-STRAHN-uh-mee). The study of radio waves which are given off by objects in outer space.

radiosonde (RAY-dee-oh-sahnd). An instrument for recording weather conditions up to 100,000 feet above sea level.

radio telescope (RAY-dee-oh TEL-uh-skohp). A large receiver for detecting radio waves given off by objects in space.

relative humidity (REL-uh-tiv hyoo-MID-ih-tee). The ratio of the water vapor in air at a given temperature to the total amount the air could hold at that temperature.

resistance (ruh-ZIS-tuns). Opposition to the flow of electrons in an electrical conductor.

respiration (res-puh-RAY-shun). The exchange of oxygen and carbon dioxide by living cells.

revolution (*rev*-uh-LYOO-shun). Movement of a planet or other object around another heavenly body.

rhizome (RY-zohm). An underground plant stem.

rocket (ROK-et). A heat engine that can operate beyond the earth's atmosphere; a vehicle powered by such an engine.

rockoon (ROK-oon). A small rocket launched from a balloon.

rotation (roh-TAY-shun). Spinning of a planet or other object on its axis.

rotor (ROH-ter). The moving part of a generator, or the moving wheel of a turbine.

rumen (ROO-men). The first chamber of the stomach of a cow and certain other animals.

ruminants (ROO-mih-nantz). Animals that have a rumen and chew a cud.

satellite (SAT-uh-lyte). An object that revolves in a regular orbit around a heavenly body.

saturated air (SACH-er-ayt-ed ayr). Air that contains all the water vapor it can hold.

seed (seed). A tiny embryo plant with stored food surrounded by a protective covering.

seedling (SEED-ling). A young plant from the time it comes out of the seed until it is able to make its own food.

sextant (SEKS-tant). An instrument for measuring the height of stars above the horizon.

skeleton (SKEL-uh-t'n). The framework that supports the body of an animal.

sonar (SOH-nahr). A sound-reflecting system for locating objects which are beneath water.

spectroscope (SPEK-truh-skohp). An instrument for forming and studying spectrums.

spectrum (SPEK-trum). The band of colors produced when light is passed through a diffraction grating or a prism.

sperm cell (spurm cell). A male sex cell.

sporangia (spuh-RAN-jee-uh). The hard, protective cases in which spores are formed.

spores (spawrz). Reproductive cells of some plants and animals which are enclosed in hard protective cases.

sori (SO-ree). Fruiting bodies found on the underside of ferns.

stamen (STAY-men). The male sex organ of a plant.

star (stahr). A heavenly body which produces its own light and heat.

static electricity (STAT-ik eh-lek-TRIH-sih-tee). Electrical charges that do not move.

stationary front (STAY-shuh-*nay*-ree front). A weather front that does not move.

stator (STAY-tor). The stationary part of a generator, or the stationary wheel of a turbine.

stigma (STIG-mah). The sticky surface at the top of a style.

stomata (STOH-muh-tuh). Openings on the surface of a leaf which enable gases and liquids to enter and leave the leaf.

stratus clouds (STRAY-tuhs clowdz). Thin, flat, layer-like clouds in the lower part of the atmosphere.

stratosphere (STRAY-tuh-sfeer). The layer of the earth's atmosphere between 10 and 30 miles above the earth's surface.

style (styl). The stalklike part of a pistil above the ovary of a plant.

surveying (ser-VAY-ing). Determination of locations on the earth by triangulation.

tadpole (TAD-pohl). The immature form of frogs and toads which lives in water and which usually has a long tail.

telemetering (TEL-uh-*mee*-ter-ing). Measurement of quantities from a distance by means of coded radio signals.

transformer (trans-FOR-mer). A device for increasing or decreasing the voltage of an alternating electric current.

transpiration (trans-puh-RAY-shun). Loss of water from the surface of a leaf.

triangulation (try-an-gyoo-LAY-shun). Using the properties of triangles to measure distances indirectly.

tropism (TROH-piz'm). A movement from within that is not the result of wish or desire.

tropopause (TROH-puh-pawz). The boundary layer between the troposphere and the stratosphere.

troposphere (TROH-puh-sfeer). The layer of atmosphere between the surface of the earth and the stratosphere.

turbine (TER-bin). An engine in which moving gas or water turns a rotor to give motion.

volt (vohlt). The unit for measuring electrical pressure or electromotive force in a current.

voltaic cell (vohl-TAY-ik sel). A device for changing chemical energy to electrical energy.

volume (VAHL-yoom). The space occupied by an object.

waterspout (WAW-ter spowt). A tornado at sea.

water vapor (WAW-ter VAY-per). Water in the gaseous state.

weather (WETH-'r). The state of the atmosphere at any time.

weight (wayt). The measure of the pull of gravity on an object.

INDEX

Air
  exploring, 89, 101
  properties of, 74
Air mass, 54, 55, 60
Air pressure, 19, 81
  altitude and, 16, 84, 101, 102
  and weather, 21, 25, 26
  gravity and, 18
  measuring, 21
  on one square inch, 19, 83
  on weather map, 67
  recording, 25, 82
  temperature and, 88, 89
Algae, 244
Altimeter, 84, 85
Ampère, André, 287
Anemometer, 30, 31
Angles, measuring, 146, 157
Animals, 190
  adaptations, 222
  digestive systems, 200, 201
  food-getting activities, 201
  growth and change, 213
  movement, 191
  nervous systems, 200, 201
  oxygen needs, 210
  plants differ from, 197
  reproduction, 216
  shapes, 220
  sizes, 218
Annuals, 245
Anticyclone, 29
Antlion, 204
Archimedes, 120
Aristarchus, 159
Armature, 307, 310
Atmosphere, 13
  layers of, 102, 108, 109
Atmospheric pressure, 21
Auxin, 224

Bacteria, 244
Baleen, 205
Ballast, 95
Balloons, flight in, 89
Barograph, 25, 26
Barometer
  aneroid, 25, 26
  mercury, 22, 26, 81
  water, 22, 24, 25, 81, 82
Barometric pressure, 24, 57, 58
Bathyscaphe, 128
Bathysphere, 127
Battery, 288, 311
Beaufort wind scale, 32, 33
Beebe, William, 127
Biennials, 245
Big Dipper, 136
Black, Joseph, 97, 100
Blizzard, 63
Boyle, Robert, 85
Budding, 217
Buoyancy
  of air, 104
  of water, 120

Calcium, spectrum of, 168
Camera, stars studied with, 164
Carapace, 211
Carbon dioxide, 97, 98, 101
Carnivore, 209
Cavendish, Henry, 91
Cellulose, 207
Cepheus, 137
Charge, electric, 259, 291
Charles, Jacques, 91, 93
Chlorophyll, 229
Chloroplast, 229
Cilia, 217
Circuit, electric, 279
Cirrus cloud, 48

Climate, 64, 65, 66
Clock, shadow, 134
Cloud, 46, 48, 49
  at fronts, 56, 57
  in thunderstorms, 58
  on weather map, 67
Cloud seeding, 51, 52, 62
Cold front, 56
Commutator, 310
Condensation, 40, 41, 46
Conductor, electric, 272, 281
Constellations, 136
Convection currents, 29
Cumulonimbus cloud, 48, 58, 269
Cumulus cloud, 48
Current electricity, 273
Cycle, 27
  in ocean, 122
  life, 245
  of air movement, 30, 35
  water, 49

Density, 80
  of air, 100, 107
  of ocean water, 122
Dew point, 44
Diffraction grating, 165
Digestion, in animals, 206
Dirigible, 95
Discharge, electric, 261
Doldrum belts, 35
Downdraft, 29, 35, 36
Draco, 137
Dragonfly, 194, 201, 202
Drebbel, Cornelius van, 122

Earth, measuring indirectly, 141, 143
Edison, Thomas, 293
Electrical energy
  changing voltage, 316
  from mechanical energy, 311
Electrical resistance, 286
Electric cell, 274, 288
Electric current, 273
  alternating, 310
  direct, 276
  induction of, 313
  safety rules, 286
Electric field, 270
Electricity, 257
  and magnetism, 302
  current, 273
  frictional, 259, 263
  generating, 311
  safety rules, 286
  static, 263, 273
  storing, 264
Electric motor, 309, 310
Electrode, 274, 276
Electrolyte, 274, 281
Electromagnet, 304
Electromotive force, 278
  and Ohm's law, 287
Electron, 262
  movement of, 263, 278, 279
Electronics, 320
Electroscope, 260
Embryo, 234
Eratosthenes, 141
Evaporation, 38, 39
  from hygrometer, 43
Exoskeleton, 196
Exosphere, 108, 109

Fabre, Henri, 250
Faraday, Michael, 312
Fathom, 125
Fay, Charles du, 259
Fertilization, 238
Filament, of light bulb, 286
Fog, causes of, 45
Force, 82, 83
Franklin, Benjamin, 259, 266
Friction, 257, 258
  and electricity, 259, 263

Frond, 241
Fronts, 56–58
Frost, formation of, 45
Fruit, 239
Fungi, 242

Galileo, 162
Galvani, Luigi, 273
Galvanoscope, 274
Gay-Lussac, Joseph, 101
Geissler, Heinrich, 262
Generator, electric, 313–316
Geotropism, 225
Germinating, of seeds, 224
Gilbert, Sir William, 258, 297
Gills, 210
Glaisher, James, 101, 102
Glaze, formation of, 50
Gnomon, 134
Goddard, Robert, 104, 105
Gravity, 86
  and floating objects, 120
Gravity pressure, 86
Guericke, Otto von, 22, 24, 86, 87

Hail, 50, 51
Hale telescope, 163
Height, measuring indirectly, 144
Henry, Joseph, 304, 312
Herbivore, 209
Hibernation, 189
High pressure area, 29
  on weather map, 68
Holland, John, 122
Hopkins, Sir Frederick, 156
Horse latitudes, 36
Howard, Luke, 48
Humidity, 41, 43
Hurricane, 61, 62
Hydroelectric plant, 315
Hydrogen, 91–96
  in water, 112
Hydrotropism, 225
Hygrometer, 42

Indirect measurement, 141, 145
  scale drawings for, 147
Instinct, 199–201
Insulator, electric, 281, 282
International Geophysical Year, 109, 122
Invertebrates, 196, 211
Ionosphere, 108

Jansky, Karl, 171
Jeffries, John, 96
Jet stream, 35, 108
Jupiter, features of, 183

Labium, of dragonfly nymph, 201
Lateral bud, 235
Lavoisier, Antoine, 97, 99, 100
Lenticels, 232
Léon, Ponce de, 136
Leyden jar, 265, 273
Lick Observatory, 162
Life cycle
  of insects, 214
  of plants, 245
Lift pump, 76, 77, 78
Lightning, 272
  safety rules, 272
  speed of, 58, 59
  theory of, 269, 271
Lightning rod, 271
Lippershey, Hans, 161
Living things. *See also* Animals; Plants
  basic patterns in, 247
  characteristics of, 189
  oldest, 246
  scientific study of, 252
  variations in, 249
Lodestone, 297
Low pressure area, 29
  in hurricane, 62

  in tornado, 61
  on weather map, 68

Magnet, 297
Magnetic field, 300, 313
  and electric current, 312
Manometer, 115
Marianas Trench, 128
Mariner II, 180, 184
Mariner IV, 183
Mars, features of, 182
Mass, and weight, 80
Measurement
  indirect, 141, 145
  of angles, 146
  of time, by shadows, 134
  scale drawings for, 147
Mercury barometer, 22
Metamorphosis, 214–215
Meteorology, 9, 68–70
Molecules
  motion in evaporation, 39
  of air, 110
  of water, 110
Molting, 218
Montgolfier brothers, 89
Moon
  distance from earth, 145, 157
  motion of, 131
  parallax angle for, 157
Morse, Samuel, 308
Mount Palomar Observatory, 163
Mount Wilson Observatory, 163

Navigation, aids for, 139
Newton, Isaac, 105
Nitrogen, 99, 100, 101
North Circumpolar
    Constellations, 137
North Star, 137, 139, 141

Observatories, 154–157, 158
Ocean depths, exploring, 116–122
Oceanography, 128
Oersted, Hans Christian, 303
Ohm, George Simon, 287
Ohm's law, 286
Omnivore, 209
Operculum, 210
Ovary, of plant, 237
Oxygen
  animals' need for, 210, 212
  discovery of, 98
  in air, 99, 101
  in water, 112
  plants and, 229, 232
  preparing, 99

Parallax, 154–157, 158
  for moon, 157
  for stars, 157, 160
Paramecium, 217
Pascal, Blaise, 26, 85
Payload
  of balloon, 96
  of rocket, 107
Perennials, 245
Petiole, 223
Photosynthesis, 229, 230
Phototropism, 224
Piccard, Auguste, 103
Piccard, Jacques, 128
Pistil, 237
Planets, features of, 177–184
Plankton, 205
Plants, 223–246
  food stored by, 233
  growth, measuring, 234
  life cycles, 245
  needs, 226
  reaction to surroundings, 223
  reproduction, 236
  seedless, 242
Pliny the Elder, 117
Pointer stars, 136
Polaris, 137

Pollination, 237
Precipitation, 49, 57
Pressure, and force, 82
Priestly, Joseph, 98, 99, 100, 230

Radar
  planets explored by, 173
  weather forecasting, used in, 70
Radio astronomy, 174
Radiosonde, 70, 104
Radio telescopes, 171–174
Radio waves, from objects in space, 171–174, 179, 184
Rain, 49, 51–52
Rainfall, 52–53, 54
Ratio, 144
Relative humidity, 41
Reproduction, 191
  budding, 217
  dividing, 217, 244
  of plants, 236, 240
Rhizome, 233
Rockets, 105–107
Rockoon, 107
Root hairs, 226
Rotor, 313, 315
Rumen, 206
Ruminants, 207

Sargasso Sea, 217
Satellites, artificial, 174
  first-manned, 109
  weather, 67, 69
Saturation, 39
Scale drawings, 147–152
Scuba-diving, 118
Sedentary animals, 197
Sextant, 134–141
Siebe, Auguste, 118
Shadow clocks, 134
Shadows, measuring by, 141
Skin-diving, 119
Sleet, formation of, 50
Snake, movements of, 193
Snorkel, 117
Snow
  flakes, 50
  formation of, 49
Sodium, spectrum of, 168
Sonar, 126
Sori, 241
Sound, depths of oceans determined by means of, 125
Space, exploration of, 161–184
Spacecraft, 174
Spectroscope, 165
Spectrum, of elements, 165
Spiders, 202
Sporangia, 241
Spores, 241
Sputnik I, 174
Stamen, 236
Star chart, 135
Stars
  constellations, 136
  motions of, 129, 132, 136, 164
  navigation by, 139
  observing, 162–174
  parallax angles of, 157, 160
  radio waves from, 171
  spectrum of, 165
  temperature of, measuring, 165
Stator, 313, 315
Stomata, 227
Stonehenge, 129, 130
Storms, 58–63
  benefits from, 63
Stratosphere, 103, 108
Submarine, 112, 124
Sun, "motions" of, 129, 131, 132
Sundial, 134
Surveying, 152
Suspended animation, 189

Tadpole, 214
Teisserenc de Bort, Léon, 102

Telemetering, 104
Telescope
  optical, 161–163
  radio, 171–174
Temperature
  altitude, effect of, 16, 101
  at fronts, 56
  atmosphere, effect of, 14
  distance from sun, effect of, 13
  in thunderstorms, 59
  of air masses, 54
  of ocean, 116, 119, 121, 122, 127
  of stars, measuring, 169
  of the atmosphere, 108
  on weather map, 67
  recording, 9, 102, 104
Terminal bud, 235
Thales of Miletus, 258
Thomson, Joseph John, 262
Thunder, 58, 59
Time, measured by shadows, 134
Tiros 1 and 8, 67
Tornadoes, 60, 61
Toricelli, Evangelista, 22, 81
Trade winds, 35, 36
Transformers, 316–320
Transpiration, 227
Triangles, measuring with, 145–154
Triangulation, 152
Tropopause, 103
Troposphere, 103
Tsiolkovsky, Konstantin, 104
Turbine, 315
Typhoons, 62

Updraft, 29, 35, 49, 62

Vacuum
  in mercury barometer, 22
  in tornado, 61
Venus, features of, 179–182
Venus's-flytrap, 232
Vertebrates, 194, 195
Volta, Alessandro, 274, 276
Volt, 278, 287
Voltaic cell, 276

Walsh, Donald, 128
Warm front, 57, 66
Water, 110–128
  air differs from, 74, 75, 80, 112
  composition of, 111
  compression of, 113
  displaced, 120
  ocean, 121
  supercooled, 51
  weight of, 79, 112, 114
Water pressure, 112–116
  in ocean depths, 127, 128
Water vapor
  at cold front, 56
  condensation of, 45, 46, 48, 49
  in atmosphere, 38, 101
  in water cycle, 49
Waterspout, 61
Weather Bureau, U. S., 61, 62, 65, 66
Weather forecasts, 66, 68–70
  and westerly winds, 37
  example of, 9
Weather map, 65–67
Weather satellites, 67
Weather stations, 9, 66, 67, 69
Westerly winds, 36, 37
Weight, 86
Wind vane, 33
Wind, 27–37
  in tornado, 60
  on weather map, 66
Woods Hole Oceanographic Institute, 122

Zodiac, 138

ACKNOWLEDGMENTS

The photographs in this book are from the following sources:

Monkmeyer Press Photo Service—Merrim, 16
Monkmeyer Press Photo Service—Engelhard, 17
Wide World Photos, 50
Walter Dawn, 54 *(top and bottom)*
Arabian American Oil Company, 54
United Press International, 60
Wide World Photos, 62
United States Weather Bureau, 67
Wide World Photos, 95
Wide World Photos, 103
Rapho Guillumette Pictures, 117
Rapho Guillumette Pictures—de Sazo, 118
Wide World Photos, 128
Mount Wilson and Palomar Observatories, 129
Alinari, Florence, 162 *(top)*
Yerkes Observatory, 162 *(bottom)*
Mount Wilson and Palomar Observatories, 163 *(top)*
Lick Observatory, 163 *(bottom)*
Official U.S. Navy photo, 164
British Information Services, 171
Mount Wilson and Palomar Observatories, 172 *(top)*
Cornell University News Bureau, 172 *(bottom)*, 173
Sovfoto, 174
NASA, 175
United Press International, 176 *(top)*
NASA/JPL photographs, 176 *(bottom)*, 177
Grumman Aircraft Engineering Corporation, 178
NASA, 179
NASA, 181
Mount Wilson and Palomar Observatories, 182, 183, 184
The Rockefeller Institute, 209
Monkmeyer, 220
Annan Photo Features—Hermes, 221
Walter Dawn, 222

Wide World Photos, 232
Walter Dawn, 233, 239, 244
Brookhaven National Laboratory, 273
Wide World Photos, 315

We wish to thank Frances L. Orkin for assistance in obtaining these photographs.

S.C.E.R.T., West Bengal
Library
Calcutta
25/3, B. C. Road

5
LIGHT
BAT